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## George Ellery Hale
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By PHILIP FOX

America has given to the world a few great men of science; happily now they are appearing in all fields in greater numbers. Dr. George Ellery Hale stands unquestionably in that choice company, and by his influence has contributed very greatly to the broadening stream. In astronomy his contributions have defined an epoch. In this journal it would perhaps suffice to review his great contributions to astronomy, but his vigorous and effective efforts in promoting coöperation among scientists in various fields, his great vision of programs of research with greater instruments in greater observatories, his daring plans, his dauntless approach toward the accomplishment of them, his convincing personality, his inspiring presence, and his great influence on the course of science of his generation call for something more.

George Ellery Hale was born in Chicago on the southwest corner of 47th Street and Drexel Boulevard. He was of English stock and of the tenth generation of his family in America. The first member of the family in America was

I. Thomas Hale, who was born in 1606, son of Thomas Hale of Hertfordshire, England. He came to America between 1635 and 1645 and settled in Newbury, Massachusetts.

The subsequent lineage is as follows:

II. John Hale, born in England in 1635
III. John Hale, Jr., 1661
IV. Richard Hale, 1690
V. Jacob Hale, 1717
VI. Jacob Hale, Jr., 1746
VII. Benjamin Hale, 1778
VIII. Benjamin Ellery Hale, 1809
IX. William Ellery Hale, 1836
X. George Ellery Hale, 1868

The mother of George was Mary Scranton Browne, daughter of Dr. Gardner F. Browne of Hartford, Connecticut. The grandfather, Benjamin Ellery Hale, a Congregational minister was the first of the family to migrate from New England. He came to Beloit, Wisconsin, in 1850. Later he returned to the East where his son, William Ellery Hale, was born at Bradford, Massachusetts. He in turn came to Chicago in 1863, shortly after his marriage.

It seems that the interest in astronomy and light phenomena, which dominated George Hale's life, was awakened very early. In his fourteenth year he built a small telescope. Soon thereafter his father, who backed him in all his scientific interests, bought a small telescope for him. At this time too he met S. W. Burnham. We may fancy how Burnham's quiet, unostentatious, but unswerving devotion to astronomy must have fired Hale. We know too that he visited frequently the old Dearborn Observatory, then a part of the old University of Chicago and directed by G. W. Hough. Even before Hale matriculated at the Massachusetts Institute of Technology he was photographing the Sun and methodically observing sunspots. While at the Institute he was associated with the Harvard College Observatory as a volunteer assistant. It would seem that his choice of college was very fortunate for the engineering courses must have helped to develop his keen interest in instruments and his extraordinary ability to conceive workable designs.

On his return to Chicago, with his father's support, he built the Kenwood Observatory in the backyard of the family home at 4545 Drexel Avenue and installed there the excellent 12-inch Brashear refractor. At this time also he built the Kenwood spectroheliograph which won for him instant fame. The general idea of the instrument had been conceived when still in college where indeed he tried an experimental design. It must have required real zeal and stalwart resolution to keep the series of plates going through 1893 with the allurements of the World's Columbian Exposition so nearby. But this year and 1894 and 1895 were in a very vigorous sunspot maximum and the series of plates shows few unwarranted gaps. Ferdinand Ellerman was his assistant at this period, bringing to the observatory uncanny observational skill and extraordinary photographic technique, beginning a life-long association.

But even in the press of his observing, I fancy Hale was often in the Manufacturers Building, looking at the mounting of the great 40-inch telescope displayed there, dreaming and planning the equipment, the research programs, and the organization of the staff of the great observatory which he had been largely instrumental in persuading Charles T. Yerkes to build.

In 1892, at the age of twenty-four, Hale was appointed to the faculty of the new University of Chicago, and immediately thereafter started his campaign for a greater observatory. In the *Astrophysical Journal* for March of 1897, he gives an account of this period, September 1892: "Mr. Yerkes' generous offer to the University, which included the assumption of the entire cost of building an equatorial refractor of forty inches aperture and housing it in a suitable observatory, was received with great satisfaction and accepted immediately." The history of the Yerkes Observatory and its great work under Hale is well known.

I write with some feeling about the Kenwood spectroheliograms for they provided the avenue through which I joined the inspiring company

that Hale had assembled at the Yerkes Observatory and began serious astronomical research. As a Carnegie Research Assistant my problem was to measure these plates to make a new attack on the problem of the solar rotation. Several things came to mind in recalling the circumstances.—First, at the time the appointment was proffered, I was a graduate assistant in physics at Dartmouth College, and had been aiding Nichols and Hull in their investigation of the pressure of radiation. I had, however, a plan to re-enter the army, and had a well-endorsed application in the War Department for re-commission as a lieutenant of infantry. I have often thought that three men: Hale, Frost, and Nichols, entered into a conspiracy (if so, a successful one) to divert my attention to astronomy.—Second, I had not been many days at Williams Bay when I witnessed a lightning flash of genius. We were considering the method of measuring the plates, the type of engine to use, and the laborious method of reduction from rectangular to heliographic coordinates when Hale exclaimed, "Why not project the plates back upon a globe representing the Sun?" The exceedingly useful globe measuring machine employed in this and subsequent investigations had such an origin.—Third, I recall standing beside the machine with Hale and Ellerman when it was being made ready for use, pausing in thought, Hale started to whistle the Vorspiel to Lohengrin, with Ellerman and me joining in, whistling on to the end, then laughing a bit and going on with adjustments. It revealed his complete absorption, and moreover his deep love for music which I saw manifested many times. In music he found soothing relaxation.—Lastly, in the first draft of the paper (later revised and printed as Carnegie Institution Publication No. 93), I wrote: "Dunér's results are so discordant when compared to the other investigations that they should be examined for systematic errors or be repeated." In Hale's response is the only instance within my knowledge in which he was swayed by the weight of authority or prestige. He blue penciled my words, saying: "Dunér's observations are classical." In general he approached every problem with the freshness of the amateur, without the inhibitions or restrictions imposed by recognition of authority or tradition. Both of us were more content, however, when Halm later called attention to the fact that Dunér in reducing his observations of the radial velocity of the Sun's limb had neglected to allow for the component of radial velocity in the Earth's orbital motion in that direction, and therefore had published synodic periods and not sidereal.

From the Yerkes Observatory, Dr. Hale moved on to Pasadena and Mount Wilson, there to establish another great observatory, gather another group of earnest men, and attain still greater success. The 40-inch refractor had originally been intended for location in that region. Hale brought still more powerful instruments. We must recognize, also, that in Hale's guiding genius the formulation of the project of the Palomar Observatory and the great 200-inch reflector had its origin and continued support. In his later years when failing health demanded that he

relinquish the directorship of the Mt. Wilson Observatory he built again a private observatory and there continued his studies when strength availed. In his first private observatory he invented the spectroheliograph; in this, his last, the spectrohelioscope.

Professor Hale's own contributions number well over four hundred. They cover a wide range of topics: descriptions of instruments, spectroscopic investigations, but for the most part they pertain to the Sun. The most conspicuous exception is found in his studies, "The Spectra of Stars of Secchi's Fourth Type." If we would survey briefly the list of titles we would find papers on the spectroheliograph and its work; on many solar phenomena revealed with its use; the adaptation of the coelostat for use with spectrographs of high dispersion, first horizontal and later the 60-foot tower, and then the soaring 150-foot tower; the advantages of great reflectors; on the 60-inch reflector for which his father provided the money, the 100-inch, and lastly the great 200-inch; the spectra of prominences recognizing the presence of lines of various elements in those of active eruptive type; identification of the H and K lines with calcium; on the spectra of sunspots; the recognition of the bands of titanium oxide and calcium hydride in their spectra; flash spectrum without an eclipse; spectrum of iron under pressure; solar vortices; the spectrohelioscope; the sunspot spectrum and its indication of temperature lower than that of the photosphere; the classification of lines of the spectra according to behavior under different temperatures; the Zeeman effect in the spectra of sunspots; the magnetic polarity of sunspots; the general magnetic field of the Sun; and so on—the tally is not half recorded.

Some of Hale's investigations must stand out in later years as of highest importance; those of sun-spot vortices and temperatures, for example. The first spectroheliograms using the Hα line of hydrogen revealed unmistakable vortices about the spots. Surprising evidence in confirmation was supplied by the observations of the Zeeman effect in lines of the sun-spot spectra interpreted in the light of the Rowland effect. Walter M. Mitchell had suggested the Zeeman effect as an explanation of the widening of certain lines, but Hale's brilliant demonstration was conclusive. The method used revealed also the strength of the magnetic fields associated with spots, their magnetic polarity, the association of the direction of vortical motion with polarity, and further still the reversal of polarity at the end of the sun-spot period, indicating the double period or twenty-three years as the true cycle. These associated phenomena and their bearing on the theory of sunspots are of transcendant importance. In looking through the folders containing my correspondence with Professor Hale, I find letters bearing on the sun-spot vortices. In discussing my measures of the Rumford spectroheliograms, I had obtained definite indications of vortices and had written to Dr. Hale giving my results prior to their publication, stating that the motion about a given type of spot was the same in the two hemi-

spheres. He immediately replied expressing surprise. I had neglected to state that I had classified motion as cyclonic and anticyclonic, not as clockwise and counterclockwise.

Of importance almost equal to that of the sun-spot vortices are the investigations on the temperature of sunspots. The associated investigations in the spectroscopic laboratory illustrate brilliantly the advantage of Hale's insistence that a physical laboratory is a necessary adjunct to an astrophysical observatory, and illustrate also his constant effort to bring sometimes widely different methods or techniques to bear on a problem, to approach in converging attack.

Mention of his publications can not be complete without citing his editorship of the *Astrophysical Journal,* appearing for three volumes as *Astronomy and Astrophysics* beginning in 1892. It is a tribute to his ability for organization and a mark of the confidence reposed in him that the following names appeared on the editorial staff: Keeler, Ames, Campbell, Crew, Frost, Wadsworth, Cornu, Dunér, Huggins, Tacchini, Vogel, Hastings, Michelson, Pickering, Rowland, Young; and that in the first number of the *Journal* appeared important papers by men of like caliber. It is amusing to see that Rowland, who but a few years earlier when Hale in his teens had asked him about a grating had replied, "Any grating of mine is good enough for an infant," should in this initial number begin publication of his Preliminary Table of Solar Wave-lengths. His inauguration of the *Publications of the Yerkes Observatory,* the *Contributions of the Mt. Wilson Observatory,* and the *Mt. Wilson Observatory Communications to the National Academy* should also be cited.

Among Dr. Hale's many publications, there are seven books:

The Study of Stellar Evolution
The Depths of the Universe
The New Heavens
Signals from the Stars
Beyond the Milky Way
Ten Years' Work of a Mountain Observatory
National Academies and the Progress of Research

These are for the most part vivid presentations of results of current investigations, up-to-the-hour reports on progressive research. The last one mentioned, however, touches on a theme particularly dear to Hale's heart, the close association of men of kindred mind, as an active stimulus to productive scholarship. He gloried in such association. He gathered about him men of keen intellect, who gave themselves unsparingly to their work. He was largely responsible for the formation of the American Astronomical Society. On the first page of the first volume of the Society's publications, it is stated that the establishment "may be traced directly to the first conference of astronomers and astrophysicists held in connection with the dedication of the Yerkes Observa-

tory." His was the guiding spirit in the organization of the International Union for Coöperation in Solar Research now transformed into the International Astronomical Union. The National Research Council was the result of his inspiration. He put new life into the National Academy, serving as its foreign secretary for many years. The transformation of the Throop Institute into the California Institute of Technology must also be attributed to him. In the volume mentioned above, he writes: "the first and best object of these bodies (Academies) must always be to uphold the dignity of research." He quotes there Laplace, "Nature is so varied in her manifestations and phenomena, and the difficulty of elucidating their causes so great, that many must unite their knowledge and efforts in order to comprehend her and force her to reveal her laws." He quotes also Napoleon: "The French people sets a higher value on the acquisition of a skilled mathematician, a celebrated painter, or a distinguished man of any profession, than upon the possession of the largest and richest city."

Dr. Hale's invitations to scholars to use the facilities of the observatories under his direction to carry on their research or undertake research for which they had special qualifications established a new practice and led to important results. Let me cite the observations by Nichols on the heat radiation of Arcturus and Vega; by Michelson and Gale on the rigidity of the Earth; by Michelson on the velocity of light and stellar diameters; by Abbot on solar radiation; by Miller on ether drift; as well as the work by Kapteyn, Eddington, Einstein, Russell, Stebbins, Duncan, and others.

In recognition of his great contributions to the advancement of science, Professor Hale received many honors. He had the Honorary Doctorate from Berlin, Manchester, Oxford, Cambridge, Beloit, California, Princeton, Pittsburgh, Yale, Chicago, Columbia, and Harvard. He was the recipient of the following medals:

Janssen Medal, Paris Academy
Rumford Medal, American Academy
Draper Medal, National Academy
Gold Medal, Royal Astronomical Society
Silva Medal, Astronomical Society of Mexico
Bruce Medal, Astronomical Society of the Pacific
Janssen Medal, Sociètè Astronomique
Galileo Medal, Firenze
Actonian Prize, Royal Institution
Cresson Medal, Franklin Institute
Franklin Medal, Franklin Institute
Gold Medal, Holland Society
Copley Medal, Royal Society

and the recipient also of the Arthur Noble Medal for Civic Service from the City of Pasadena—a recognition of Hale as a great citizen.

Moreover the leading scientific societies and academies of the world

elected him to Honorary Membership; to name a few, perhaps half of the many: The Royal Society, London; Accad. dei Lincei, Rome; Amsterdam Academy of Sciences; Institut de France; Vienna Academy of Science; Royal Astronomical Society; Royal Society, Upsala; Accademia Gioenia, Catania; Royal Institution, London; British Association; London Physical Society; Cambridge Philosophical Society; Edinburgh Royal Society; Royal Irish Academy; Paris Academy; Belgian Academy; Russian Academy of Science; *et cetera.*

George Hale found science an exciting adventure. He took delight in the acquisition of knowledge. He recognized the quickening effect of a brilliant company of scholars. Each day he awoke to hours of useful endeavor. One need not have known him long to realize the joy he experienced in visits to great centers of learning, in Egypt to delve with Breasted among the pyramids and stand over the site of the ancient school and library of Alexandria; in Paris which gives visible recognition to her scholars. One can readily see his quick response reviewing in his mind the careers of them for whom Paris streets and squares are named: Boulevard Arago, Rue Auguste Comte, Rue Cassini, Rue Cuvier, Rue Buffon, Rue Geoffroy St. Hilaire, Place Monge, Rue Laplace, Rue Descartes, Rue Linné, Rue Champollion, Boulevard Pasteur, Rue Lavoisier, Avenue Carnot, Rue Colbert, Rue Lagrange, Rue Lamarck, Rue Fermat, Rue Fresnel, Rue Claude Bernard, Rue Cauchy, Rue Foucault, Rue Le Verrier; and his pleasure that the recognition goes beyond the national borders—Rue Franklin, Rue Huygens, Rue Herschel, Rue Léonard de Vinci, Rue Euler, Rue Newton. He has written of this in the introduction to Science and Learning in France, under the title, "The Intellectual Inspiration of Paris."

Dr. Hale was the ideal director for an observatory and would have been for any other scientific institution. His mind was seething with plans for research and the plans were no sooner conceived than they were put into action. Of him it might also be said that he was "fertile in resource." He was generous to his staff in acknowledging their participation, often disclaiming his part. He planned instruments to attack problems not limiting his choice of problem to the means of attack. He formulated problems with crystal clarity; he loosed "the hold which old and established methods of thought often retain." It will be of intense interest to see if the great 200-inch telescope discharges honorably the rôle he defined for it. He dared to plan for it, dared to frame its program, dared have confidence in engineers to fashion it, and in his colleagues to use it and interpret their findings. A stream of astronomers poured through the Yerkes Observatory of his day, zeal kindled by his enthusiasm, to become in turn directors: Adams, Mitchell, Schlesinger, Slocum, Jordan, Wright.

I would not wish to give the impression that George Hale was always intense, relentlessly driving himself and his associates. He could and did work at fever heat, but those who have seen him at Orchestra Hall or at the opera have sensed his love of music; those who have seen him

reenact the puppet show exploits of the brave knight, Rinaldo, which he had ventured to see in Sicily, or heard him recite the tales from Monasteries of the Levant know his keen dramatic sense and his deep and abiding appreciation of humor. He was a most delightful companion, equally eager as an auditor or raconteur. In his last years as he became more frail, his friends regarded him with reverence—to see him was a privilege; to be in his presence a benison.

He married Evelina Conklin of Brooklyn in 1890, shortly after finishing his course at Massachusetts Institute. His home life, shared also by his two children, Margaret and William Ellery, whom he, and all of us at Williams Bay, called "Willum," was one of earnest devotion. He delighted to speak of Margaret's six daughters, and William's two sons.

His brother William B. Hale, who somewhat in looks and decidedly in speech bears him resemblance, and his sister Martha, wife of General William W. Harts, also survive him.

George Ellery Hale was a man who loved nature intensely; he rejoiced in its study. He knew that "the basis of science is the knowledge of natural law." He attained to a "vast conception of an ordered cosmos, stretching away to the countless island universes beyond our own galactic island in which the solar system is as a grain of sand. In this conception we may glimpse the imprint of a creator, infinitely above the tribal deities of early man, whose immutable laws it is our first duty and greatest advantage to discover and to obey."* He never strove for individual advantage. More than most men he had learned

*"To set the cause above renown*
*To love the game above the prize."*

He loved his fellow men, he was loyal and won loyalty, admiration, and deep affection. He was the kindest, most considerate, most generous, most steadfast of friends.

Museum of Science and Industry,
Chicago, Illinois, 20 September 1938.

*Building the 200-inch Telescope, *Harpers Magazine*, November, 1929.

## ODE

Before I slept,
Through frosty mists over the Lake
Sirius, valiant, pierced the fog but
Faint and pale glowed his near companions.
All other lesser lights of heav'n were hid.

Now skies are cleared.
Golden, the half-moon is at zenith: now
Like a mighty freighted ship, prow cutting through
Deep heavenly seas, Orion tilts to westward.

And where Murzim clears his path, and
Flashing in Orion's wake great Sirius
Invades the star-defended sea of night ahead—
Haughty, presuming victory!

Miss Lulu Barker.
1223 Elmwood Avenue, Evanston, Illinois.

# The Observation and Interpretation of Stellar Absorption Lines

By OTTO STRUVE

The subject of our discussion is a relatively new branch of astrophysics. Its origin may be placed, with some confidence, in the year 1924, when H. N. Russell and J. Q. Stewart of Princeton made what appears to be the first successful attempt to explain the observed widths of the absorption lines in the spectrum of the sun. Then, in 1927, A. Unsöld published in the *Zeitschrift für Physik* a paper under the title "Über die Struktur der Fraunhofer'schen Linien und die Dynamik der Sonnenatmosphäre." In this important paper he derived the theoretical profiles of the calcium lines H and K in the spectrum of the sun and compared them with the true profiles observed by Schwarzschild. The fundamental progress of Unsöld's work consisted in the combination of three distinct theories: the theory of the atomic absorption coefficient which gives the relation between absorbing power and wave-length; the theory of excitation and ionization, which gives the number of atoms in the state suitable for absorbing the line under consideration; and the theory of the propagation of light through stellar atmospheres, which gives a relation between the intensity of the transmitted light, the atomic absorption coefficient, and the number of atoms. These three theories had been separately developed to a high degree of perfection before 1927 and their combination led to an exceedingly fruitful development, the study and interpretation of the profiles of stellar absorption lines.

## I. Radiation Damping

The classical theory of the atom in which the electron is considered as a simple harmonic oscillator of a definite frequency $\nu_0$ predicts that the atom will absorb, or emit, light not only of the exact frequency $\nu_0$, but also of neighboring frequencies $\nu$. This effect can be easily derived from the classical electron theory, and it is shown that the power of the atom to absorb incident light is greatest at $\nu_0$, decreasing on both sides of this frequency approximately as $1/(\nu-\nu_0)^2$. The exact form of the absorption coefficient is given by the expression

$$\sigma = \frac{C^1\gamma}{(\gamma/2)^2 + 4\pi^2(\nu-\nu_0)^2}. \qquad (1)$$

Here $\gamma$ is a very small constant, called the natural damping constant, while $C^1$ is another constant which depends upon the physical properties of the electron: its mass, charge, etc. It is obvious that when $\nu = \nu_0$ the absorption coefficient has its maximum value. Numerically this value is large because $(\gamma/2)^2$ is small. Obviously, $\sigma_{max} = 4C^1/\gamma$.

It requires a certain amount of explanation why an oscillator whose

frequency is $\nu_0$ should be sensitive to any other frequency. The reason, on the classical picture of the atom, is that while the atom emits radiation its amplitude decreases. The phenomenon is essentially analogous to that of a damped vibration. Hence, the designation "radiation damping." The wave train emitted by the atom has the equation

$$Y = A_0 e^{-\gamma t/2} \cos 2\pi\nu_0 t$$

where the exponential term represents the damping of the amplitude. Now in optics we learn that we can describe the various phenomena correctly if we attribute to every frequency an *infinite* train of waves of *constant* amplitude. Hence Y must be represented as the sum total of infinite wave trains of different frequencies. This may be accomplished by representing Y as a Fourier integral. The resulting coefficients give the constant amplitudes of the individual wave trains and their squares determine the intensities of the light of different frequencies.

If we designate the number of absorbing atoms by N and the thickness of the absorbing layer by H, we call the quantity

$$\tau = \sigma NHf \qquad (2)$$

the optical thickness of the absorbing layer. The constant f is a somewhat peculiar, dimensionless, quantity—the oscillator strength. It is required because in reality the atom does not consist of a simple harmonic oscillator having only one fundamental frequency, $\nu_0$. The oscillator strength is a factor which expresses how many classical oscillators are required to produce the same amount of absorption as one real atom. This factor f is always small. For many important lines it can be determined by means of quantum-theoretical computations. Thus for the K line of ionized calcium $f = 2/3$, while for the H line $f = 1/3$.

The constant $\gamma$ in (1) is of great importance. Its physical significance is that it measures, in a classical oscillator, the effect of damping which results from the continuous loss of radiation—energy by the vibrating oscillator. For the oscillator $\gamma$ can be computed. It turns out to be so small that the central value of the absorption coefficient $\sigma_{max}$ is very large.

If we were considering an emission line, undisturbed by other effects, its profile would be given by the form of the function $\sigma$. In the case of an absorption line the problem is more complicated. We picture the processes taking place in a stellar atmosphere in the following way: the photospheric radiation from the deeper parts of the star passes through the cooler and thinner gases of the reversing layer and is partly absorbed by the atoms. In the process of absorption the atoms are excited to higher-energy states. Each atom, after a short interval of time ($\sim 10^{-8}$ sec.) spontaneously, or under the stimulation of the radiation field, releases the absorbed quantum of light. But while the original quantum came from below, the released quantum has no preferential direction. Some quanta are returned into the outgoing beam, thereby partly reinforcing the observed radiation. Other quanta are sent back

into the star.

In order to deal with the absorption problem adequately it is necessary to solve the so-called equations of transfer of energy through a stellar atmosphere. This has been done and we know how the intensity of the transmitted light is related to the optical thickness $\tau$. In order not to complicate the discussion we shall use only the simplest case of transfer—that which converts all absorbed energy into some other form of radiation which does not affect the intensities within the absorption line or in its immediate neighborhood. When this condition is fulfilled the observed intensity at any point within the line

$$I = I_0 e^{-\tau} , \qquad (3)$$

where $I_0$ is the intensity of the continuous spectrum near the line; $\tau$ is, of course, a function of $\nu$ (the frequency) or $\lambda$ (the wave-length). Hence I may be plotted as a function of $\lambda$. The resulting curve is the profile of the absorption line.

Equation (3) cannot always be used since it completely neglects the process of reemission by the excited atoms and takes no account of the continuous absorption in the stellar atmosphere. We consider the reversing layer as perfectly transparent to all radiations except those within the lines, and we attribute the star's continuous spectrum to a separate layer—the photosphere. This rather crude picture has now been largely abandoned in so far as the normal reversing layer is concerned. But the results obtained by the simple theory can be reinterpreted in the light of more modern theories. Furthermore, we shall discuss in Sections VII, VIII, and IX the origin of absorption lines in distant shells surrounding the stars, and, for this problem, expression (3) should be quite sufficient.

The profiles corresponding to (3) have been drawn (Fig. 1) for different values of N in (2). It is, of course, necessary to substitute (1) in (2), and (2) in (3). We may then compare the theoretical profiles with the observed profiles. If the shape of the curves is in satisfactory agreement, we may next adjust the disposable constant N in such a way that we obtain the best possible agreement between the theory and the observations. The value of N found in this manner is the observed number of atoms per cubic centimeter of the element under consideration, which happen to be in the required stage for absorbing the particular line. If we are dealing with H and K of ionized calcium, N gives us, effectively, the number of ionized calcium atoms per cubic centimeter. If we are considering a line which originates, not from the ground level, but from an excited level, N is the number of atoms per cubic centimeter in that particular level. In order to obtain the total number of atoms in the given stage of ionization we must divide N by the fraction which represents the relative number of atoms in the energy level which we are investigating. For a stellar atmosphere in thermodynamic equilibrium, this fraction is given by Boltzmann's relation

$$N = N_0 e^{-\chi/kT} , \qquad (4)$$

where $\chi$ is the energy of the state, k is the Boltzmann constant, and T is the temperature.

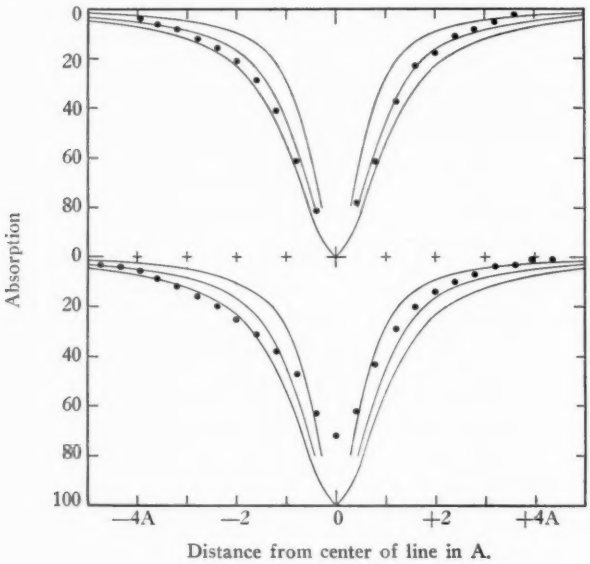



FIGURE 1

Profiles of lines produced by radiation damping. The three curves are for $NHf = 1 \times 10^{17}$, $2 \times 10^{17}$, and $3 \times 10^{17}$. The observations are for H$\beta$ in $\epsilon$ Aurigae in 1929-30 (top) and 1930 (bottom).

The theory of the natural broadening of spectral lines has been amply tested. It is found to be essentially in agreement with the observations. Only near the center of the line (3) requires almost complete absence of light, because $e^{-\infty} = 0$ and because $\tau$ is very large when $\nu = \nu_0$. The observed spectral lines are, however, never completely dark in the center. The discrepancy has bothered us for many years, but it now seems to have found a satisfactory explanation. We shall not discuss this phenomenon here, and I merely wish to refer you to Unsöld's new book "Die Physik der Sternatmosphären," where the matter is fully discussed.

When the absorption lines are very weak it is not possible to derive from the photographs reliable profiles. We are, then, compelled to use another test. We define as the total absorption of a line (equivalent breadth) the value

$$A = \int_{-\infty}^{+\infty} (I_0 - I)\, d\lambda \,. \tag{5}$$

If we again insert (1) in (2), (2) in (3) and, finally, (3) in (5) we find that there is direct proportionality between A and $\sqrt{NHf}$ (provided the term $(\gamma/2)^2$ in the denominator of (1) is dropped):

$$A \propto \sqrt{NHf} \,. \tag{6}$$

This square-root law is of great importance and can easily be tested. Consider, for example, the members of a single multiplet in a single star. The thickness of the reversing layer H is, of course, the same for all lines. The values of Nf, on the other hand, are proportional to the multiplet intensities. Accordingly, we can plot the observed values of log A against the logarithms of the multiplet intensities. The result should be a straight line with slope 1/2, because from (6):

$$\log A = \tfrac{1}{2} \log NHf \tag{7}$$

This test has been carried out for many stars and has been found to agree with the observations for all very strong lines, other than those of hydrogen, and for many weaker lines. Thus, the strong lines H and K of ionized calcium give

$$\frac{A_{\text{CaII K}}}{A_{\text{CaII H}}} = \sqrt{\tfrac{2}{3}} / \sqrt{\tfrac{1}{3}} = 1.414$$

Another interesting case is that of the triplet of Si III: λλ4552, 4567, 4574. The theoretical multiplet intensities are 5:3:1; the observed total intensities in several stars give

$$A_{4552} : A_{4567} : A_{4574} = \sqrt{5} : \sqrt{3} : 1.$$

## II. Thermal Doppler Effect

The theory of radiation damping has been developed under the assumption that the atoms are quiescent and undisturbed by each other. If the atoms are in motion the theory must obviously be corrected.

Let us consider the case in which the velocities of the atoms are distributed according to Maxwell's law. In that case the fraction of atoms dN/N which have radial velocities between v and v + dv is given by an expression resembling the error function:

$$dN/N = \frac{1}{v_0 \sqrt{\pi}}\, e^{-(v/v_0)^2}\, dv \,. \tag{8}$$

Here $v_0$ is a constant which measures the average speed of the atoms. In fact $\tfrac{1}{2}v_0^2$ is the mean of all values of $v^2$. If the motions of the atoms are produced by the temperature of the gas, then $v_0$ measures this temperature, according to the following relation:

$$v_0 = \sqrt{2RT/\mu} \,, \tag{9}$$

where R is the gas constant and $\mu$ is the molecular weight of the gas.

Equation (8) represents a frequency distribution which tells us for any value of v the relative number of atoms moving with that velocity. Every atom absorbs a certain amount of energy in accordance with (1). If the atom is moving we have

$$\sigma = \frac{C'\gamma}{(\gamma/2)^2 + 4\pi^2(\nu - \nu_0 - \Delta\nu)^2}, \tag{10}$$

where $\Delta\nu$ is the shift in frequency which results from the velocity v. We now imagine that our N atoms within each cubic centimeter are broken up into an infinite number of groups, each having its own constant velocity v. Then the number of atoms in each group

$$dN = N\phi(\Delta\lambda), \tag{11}$$

where $\phi(\Delta\lambda)$ designates the frequency function (8) converted from v as the independent variable to the new variable $\Delta\lambda$ ($v = \Delta\lambda \times c/\lambda_0$). If $\sigma(\nu - \nu_0)$ in (10) is also converted to $\sigma(\Delta\lambda)$ by means of the substitution $(\nu - \nu_0) = (c/\lambda^2)\Delta\lambda$, we find for the absorption coefficient

$$\sigma^* = \frac{\int_{-\infty}^{+\infty} \sigma(\Delta\lambda - \Delta\lambda_0)\,\phi(\Delta\lambda)\,d(\Delta\lambda_0)}{\int_{-\infty}^{+\infty} \phi(\Delta\lambda)\,d(\Delta\lambda)}. \tag{12}$$

The meaning of this integration is easy to understand. We draw the function $\sigma(\Delta\lambda)\phi(0)$ on a suitable scale against $\Delta\lambda$ as abscissa. We then shift the entire curve a small distance $\Delta_1\lambda$ and multiply all its ordinates by the factor $\phi(\Delta_1\lambda)/\phi(0)$. We next shift the curve of $\sigma(\Delta\lambda)\phi(0)$ by $\Delta_2\lambda$ and multiply all ordinates by $\phi(\Delta_2\lambda)/\phi(0)$. Proceeding in this manner we obtain a series of curves. The integration in the numerator of (12) is the sum of all the ordinates at any given point on the abscissa, $(\Delta\lambda_0)$. But the total amount of energy absorbed by the N atoms must remain constant. Hence the result of the integration in the numerator must be divided by the area of the curve $\phi(\Delta\lambda)$.

If the Doppler effect is large the shape of $\sigma^*$ will be similar to that of function (8). If the Doppler effect is small the shape of $\sigma^*$ resembles that of function (1). Since (8) is more or less bell shaped, having rather steep sides and faint wings, while (1) is quite narrow near the center and has sloping sides with strong wings, the tendency will be for $\sigma^*$ to resemble an error curve in the middle and a radiation-damping curve in the wings.

If numerical values are introduced, the core resembling an error curve turns out to be very narrow for all atoms except hydrogen and helium. The former are subject to large disturbances by electrical fields, but some of the lines of He I are practically free of Stark effect. Some of these lines seem to show a core of about 0.5 A in width in stars of low luminosity such as $\tau$ Scorpii and $\gamma$ Pegasi. These cores are probably caused by the thermal Doppler effect, but the evidence is not conclusive.

We can obtain more information if we again consider the total absorptions:

$$A = \int_{-\infty}^{+\infty} (I_0 - I)\, d\lambda = I_0 \int_{-\infty}^{+\infty} (1 - e^{-\sigma^* NHf})\, d\lambda . \qquad (13)$$

When Doppler effect predominates to such an extent that radiation damping may be neglected altogether we find:

$$A = 10^{-13} \sqrt{\pi}\, NHf \left\{ 1 - \frac{10^{-13} NHf}{\Delta\lambda_0\, 2!\, \sqrt{2}} + \frac{(10^{-13} NHf)^2}{(\Delta\lambda_0)^2\, 3!\, \sqrt{3}} - \cdots \right\} . \qquad (14)$$

When NHf is small enough, so that the second and higher terms in the series may be neglected ($NHf \sim 10^{12}$; $\Delta\lambda_0 \sim 1A$), then A is directly proportional to NHf. But as NHf increases the second term becomes more important, and the result is that A increases less and less rapidly with NHf. If we plot log A against log NHf we obtain the "curve of growth." For small values of NHf the curve is a straight line with a slope equal to one; for larger values of NHf the curve falls gradually below the straight line, becoming almost horizontal for very large values of NHf.

We could, mathematically, pursue the course of the curve of growth as NHf tends toward infinity, but this would be useless, because for large numbers of atoms the wings produced by radiation damping gain in importance and finally dominate the entire picture. The curve of growth, therefore, rises again, after its nearly-horizontal stretch, and finally approaches the asymptote $\log A \propto \frac{1}{2} \log NHf$.

The flat part of the curve of growth falls near $A = 0.1\text{Å}$ for $T = 6{,}000°$. It depends upon the temperature and the molecular weight, and it is best to plot several curves of growth with $v_0$ as the parameter. Then we can always, with the help of equation (9), interpolate the right curve for given values of T and $\mu$.

There is one other complication. The square-root branch of the curve of growth gives $A \propto NHf$. However, the numerical constant of proportionality depends upon the value of the damping constant $\gamma$. The classical value of $\gamma$ is definitely too small. The quantum-theoretical value cannot be computed for all lines because it involves the life time of the atom in both—the upper and the lower—states. These life times are known for only relatively few lines.

It is advisable, therefore, to draw several curves with different values of $\gamma$. This has been done in Fig. 2, where the parameter b stands for our $v_0$. This b is simply the displacement $\Delta\lambda_0$, which corresponds to $v_0$. For example, when $b = 0.1$ we have $v_0 = 7$ km/sec. Assuming a molecular weight $\mu = 50$, relation (9) gives $T = 3 \times 10^5$ degrees. If $b = 0.03$ we have $v_0 = 2$ km/sec and $T = 10^4$ degrees. The number N in Fig. 2 stands for the quantity which we have designated by NHf.

The diagram shows that the flat parts of the curves of growth are separated approximately by $(\log b_1 - \log b_2)$. Since the total range of temperatures in the spectral sequence corresponds to a factor of about

100 (1500° to 150,000°) and since relation (9) contains a square root, we infer that the entire range of possible curves of growth should lie well within the two curves in Fig. 2 drawn for $b = 0.01$ and $b = 0.1$. Most stars will cluster around the dotted curve for $b = 0.03$.

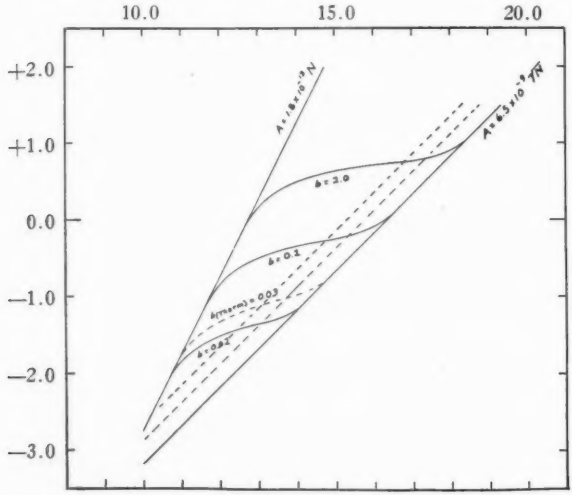



FIGURE 2
Theoretical Curves of Growth. The abscissae are log NHf; the ordinates are log A.

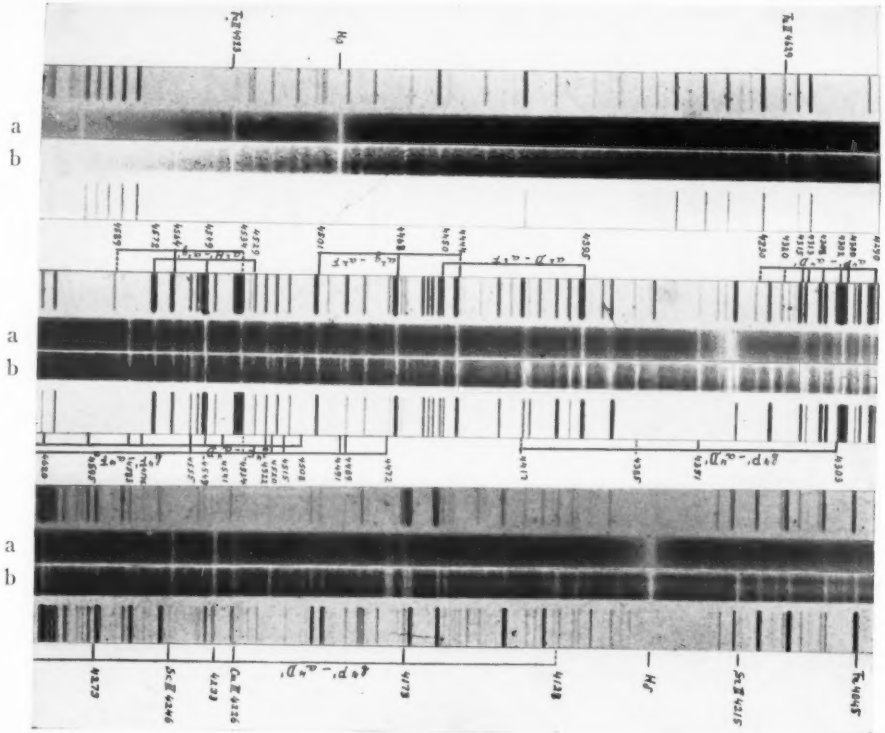
The straight line $A = 6.5 \times 10^{-9}\sqrt{NHf}$ was drawn with the classical value of $\gamma$. The other two straight lines have damping constants of four and ten times the classical value.

Observations by Minnaert and Mulders, and by Allen, together with their discussion by King, Allen, and Menzel, Baker, and Goldberg, show that the total absorptions of the Fraunhofer lines in the spectrum of the sun agree well with the curve of growth computed with consideration of thermal Doppler effect and with a damping constant which is about ten times larger than the classical value. This curve of growth is shown, among others, in Fig. 3 d.

Many stars observed at the Yerkes Observatory also show agreement with the theoretical curve of growth for thermal Doppler effect. Examples are Sirius (Fig. 3 f) and Vega (Fig. 3 g). It is probable that most dwarfs of later spectral types obey their curves of growth. For all stars the damping constant seems to be about ten times larger than the classical value.

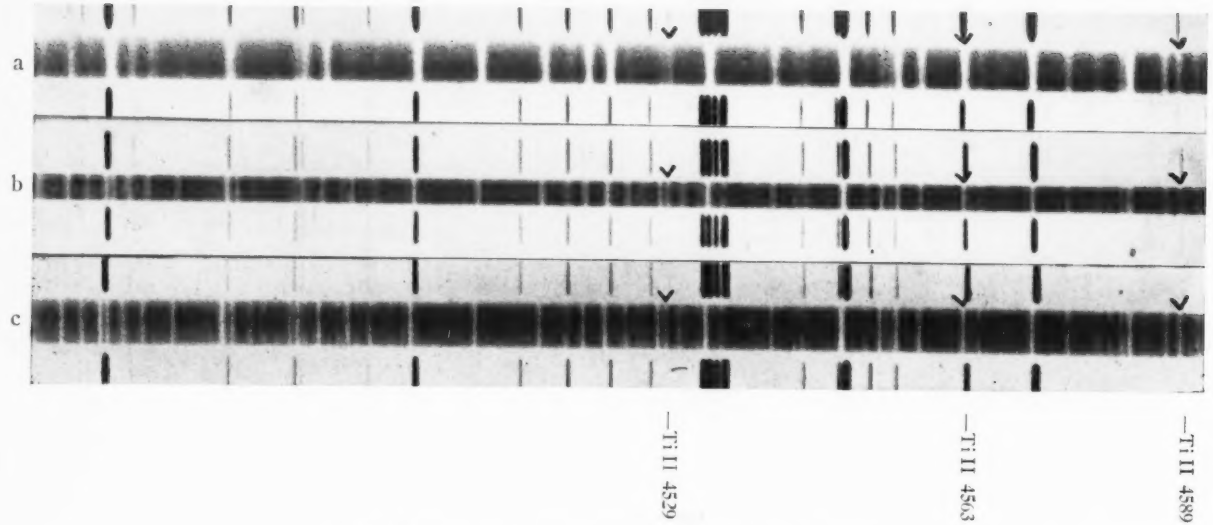
Once the curve of growth has been established for any given star, we may use the diagram to convert observed total absorptions of lines into numbers of atoms. Since the curve is rather complicated, and may vary

PLATE VIII




THE EFFECT OF TURBULENCE IN STELLAR SPECTRA.
a: 17 Leporis; b: ε Aurigae.

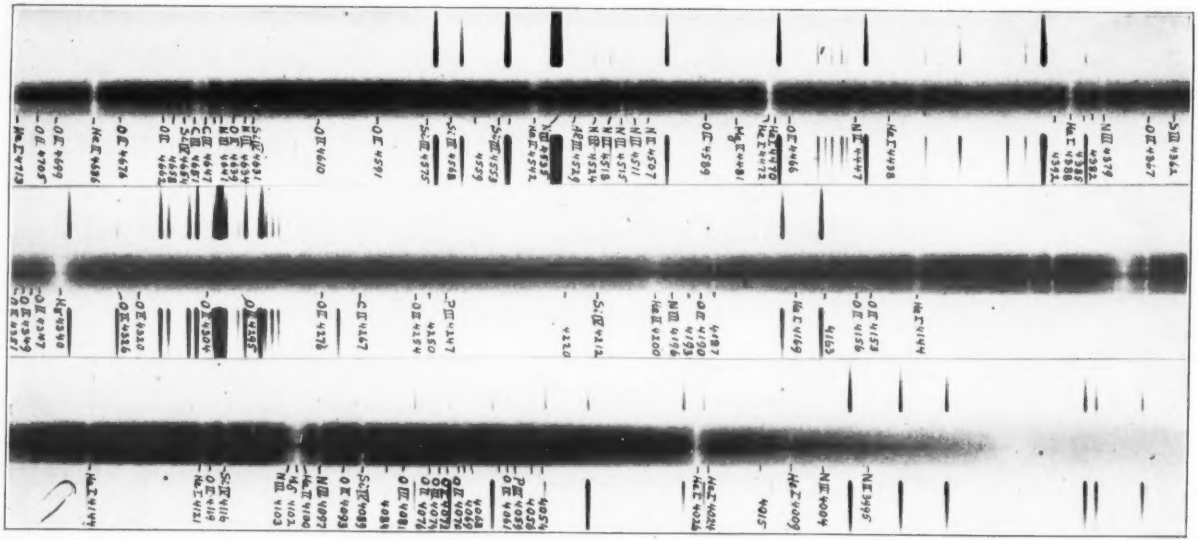
PLATE IX




THE EFFECT OF TURBULENCE IN STELLAR SPECTRA.

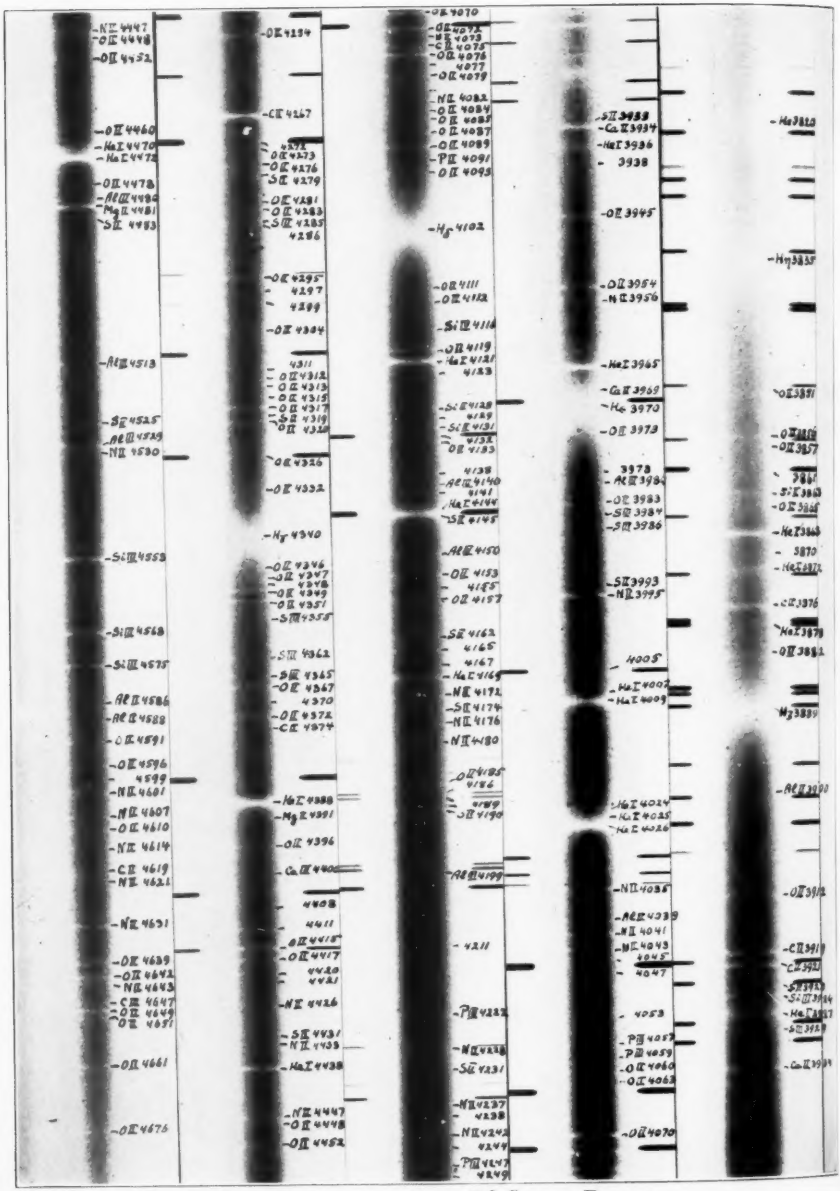
a: $\epsilon$ Aurigae; b: $\alpha$ Persei; c: 41 Cygni. Notice that the stronger lines are greatly enhanced in $\epsilon$ Aurigae, while the weaker lines appear only in the other two stars. The spectral types are approximately the same.

PLATE X



THE SPECTRUM OF THE O STAR 10 LACERTAE.

Notice the lines of ionized helium λλ 4200, 4542 which are appreciably broadened by Stark effect.



THE SPECTRUM OF THE B2 STAR γ PEGASI.
Notice that the He I line λ3872 is broad and hazy.

from star to star, it is not permissible to assume that the total intensities are always proportional to NHf or to $\sqrt{NHf}$.

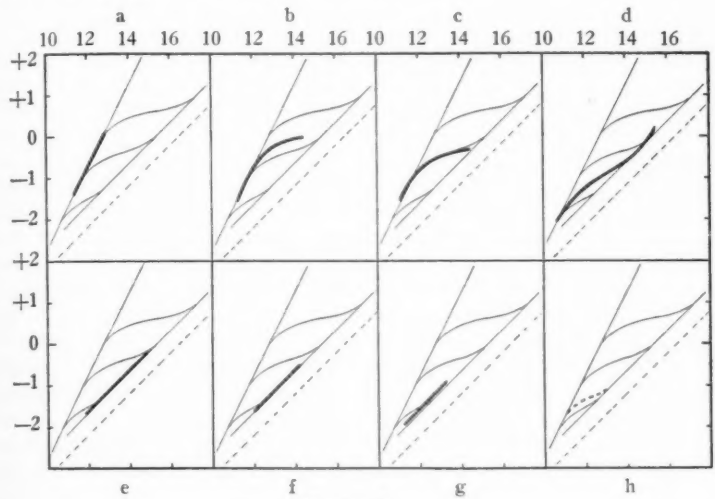



FIGURE 3

Observed Curves of Growth.

Upper row: 17 Lep.; $\epsilon$ Aur.; $\alpha$ Per.; Sun. Lower row: $\alpha$ Cyg.; $\alpha$ CMa.; $\alpha$ Lyr.; Theory (dotted curve for T = 10,000°). The damping constant of the solid lines is ten times the classical value.

## III. TURBULENCE

The construction of curves of growth, in practice, proceeds as follows: we select as many multiplets of each element as we are able to measure and discard all lines which are seriously blended. For each multiplet we construct a diagram relating A and the theoretical multiplet intensity. If relative intensities within supermultiplets are available we extend the diagrams to include several multiplets. Next we combine the separate diagrams by shifting them along the axis of NHf until the best possible fit is obtained.

This latter procedure is unsatisfactory because it involves arbitrary shifts. However, if care is taken to avoid preconceived ideas as to how the curve of growth should run, fairly reliable results are obtained. Dr. Menzel has informed me that he has attempted to reconstruct the curves of growth from our published data with the use of supermultiplets alone. The result was not very promising, leading him to question the reliability of the measures, and, of course, also of the curves of growth obtained by us in 1934. I believe the explanation of Menzel's negative result must lie in the great reduction of observational material which is unavoidable when supermultiplets alone are used. Not only is it neces-

sary, in this method, to limit the discussion to a single element, within a single stage of ionization, but lines not included in the supermultiplets must all be dropped. The precision of the measures is low and blends are dangerous. The material cannot be reduced.

Whatever the explanation of Menzel's negative result, the general features of our curves of growth are well established. Some of them have also been derived by Dunham, with satisfactory agreement in individual stars. There is in my mind a slight amount of doubt in regard to our curve of growth for α Cygni. This spectrum gives the visual impression of a fairly large amount of turbulence. I should not be surprised if it would ultimately be shown to have a steep branch for small A and a flat branch for large A.

The method of building up a curve of growth can best be explained by means of the illustration in Plate VIII. The spectra of 7 ε Aurigae and of 17 Leporis are shown side by side. Several multiplets of Fe II are marked at the top of each strip, while several multiplets of Ti II are marked at the bottom. Consider as an example the Fe II multiplet $b^4F'$-$a^4D'$. Seven lines have been measured with the microphotometer in both stars, and are listed in Table I. The unit of total absorption here is not the angstrom but a quantity which is proportional to the angstrom and which has been adjusted in such a way that the sum of all intensities in each star is 100. This makes the measured intensities directly comparable to the theoretical multiplet intensities which are adjusted in the same manner.

TABLE I

TOTAL ABSORPTIONS OF LINES IN A MULTIPLET OF FeII

| λ | Theor. Int. | ε Aur. | 17 Lep. |
|---|---|---|---|
| 4583 | 36 | 22 | 26 |
| 4549 | 25 | 19 | 27 |
| 4522 | 16 | 15 | 19 |
| 4508 | 10 | 13 | 13 |
| 4620 | 4 | 8 | 5 |
| 4576 | 5 | 12 | 4 |
| 4541 | 4 | 11 | 7 |

If we plot the theoretical intensity against the measured stellar intensity we obtain a branch of the curve of growth. The interesting thing here is that this branch does not have the same slope in the two stars. The strong lines are relatively stronger in 17 Leporis while the weak lines are relatively stronger in ε Aurigae. This effect was, when first discovered at the Yerkes Observatory, designated as the gradient effect of spectral line intensities. We now know that we are dealing with differences in the curves of growth.

A similar comparison of three stars is shown in Plate IX. The stars are ε Aurigae, α Persei, and 41 Cygni. Three lines of Ti II have been marked: λλ 4589, 4563, and 4529. The strongest line is exceedingly intense in ε Aurigae, while the weakest line is about equally intense in the three stars. The gradient is largest for the giant ε Aurigae and least

for the dwarf 41 Cygni. The temperatures of the three stars are the same, since they all belong to class F.

The final curves of growth for some of these and for other stars are collected in Fig. 3. The heavy lines are the observed curves, while the frame of light lines shows the theoretical curves already given in Fig. 2. The damping constant was set at ten times the classical value. The dotted line shows the square-root branch computed with the classical value of $\gamma$.

It will be seen at once that the curves of growth of 17 Leporis, $\epsilon$ Aurigae, and $\alpha$ Persei are not in harmony with their temperatures. The shapes of the curves bear a striking resemblance to the theoretical curves, but the resulting temperatures are quite ludicrous: $3 \times 10^7$ degrees for 17 Leporis, $2 \times 10^6$ degrees for $\epsilon$ Aurigae, and $3 \times 10^5$ degrees for $\alpha$ Persei. The spectra of these stars are well known and there can be no doubt that their real temperatures are $10^4$ degrees for 17 Leporis and about $6 \times 10^3$ degrees for the other two stars. The discrepancy is beyond every reason, and can, of course, not be due to errors in the observations.

There can be only one explanation: the gases which form the atmospheres of these stars are in a state of turbulent motion which greatly exceeds the thermal motions of the individual atoms. How this motion is produced we do not know. But that it is really present cannot be doubted. The curves of growth give unmistakable evidence. But even the line-profiles show that they are caused by Doppler effect.

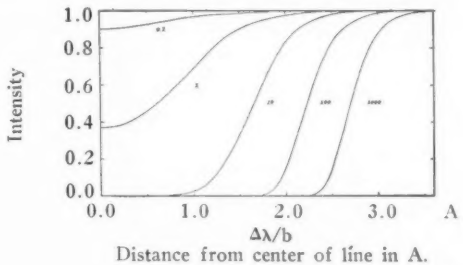



FIGURE 4
Theoretical profiles of lines produced by Doppler effect (Turbulence).

Fig. 4 shows several theoretical profiles of lines produced by turbulent motions. The ordinates are intensities in percentages of the intensity of the continuous spectrum. The abscissae are values of $\Delta\lambda/b$ and the parameters of the various profiles are $10^{-13}$NHf. Consider, for example, a turbulent Doppler effect for which $b = 1$A. Then the abscissae are angstroms and the parameters are $NHf = 10^{12}$; $NHf = 10^{13}$; $NHf = 10^{14}$; $NHf = 10^{15}$, and $NHf = 10^{16}$. For a small number of atoms the line is shallow, but broad—about 3 A in total width. For $10^{16}$

atoms the line is completely black in the middle and the width is about 6A. These are exactly the profiles as we observe them in such stars as 17 Leporis and $\epsilon$ Aurigae. They differ radically from the pointed profiles (Fig. 1) computed on the basis of radiation damping alone or even on the basis of radiation damping plus thermal Doppler effect.

In order to take account of turbulent velocities in the theoretical curves of growth we use equation (12) or (13), but we modify expression (9):

$$v_0 = \sqrt{2RT/\mu} + v_{Turb}. \tag{15}$$

In this manner the most frequent turbulent velocity $v_{Turb}$ is found to be 67 km/sec for 17 Leporis, 20 km/sec for $\epsilon$ Aurigae, and 7 km/sec for $\alpha$ Persei.

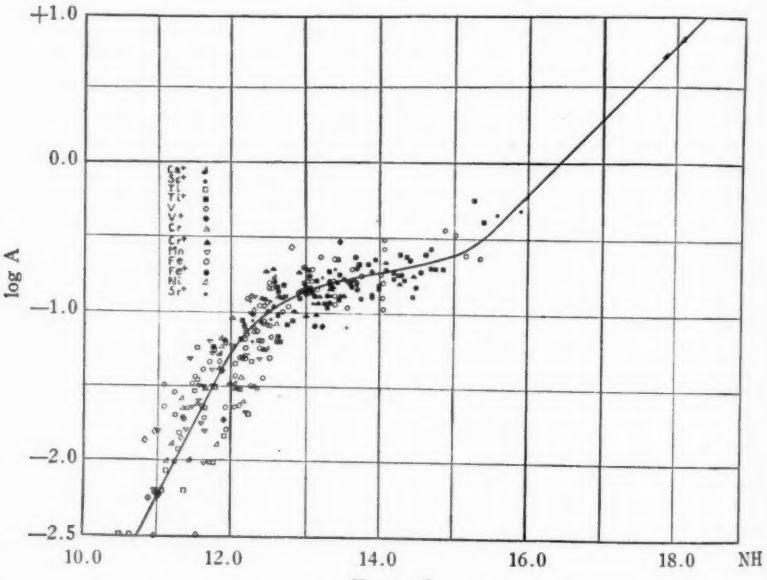



FIGURE 5
Curve of growth for R Coronae Borealis (by Berman).

The recognition of large turbulent velocities in many stars is one of the most interesting results of recent years. One of the best stellar curves of growth known is that of R Coronae Borealis determined by Berman (Fig. 5). The turbulent velocity $v_{Turb} = 10$ km/sec. Berman used for his calibration the supermultiplet intensities which were computed by Menzel and by Goldberg at the Harvard Observatory. In his final curve of growth he combined the results from several different elements.

Large turbulence is found predominantly in supergiants of all spectral classes, and in such peculiar stars as P Cygni, $\beta$ Lyrae, etc. All of these stars doubtless possess very large atmospheres.

## IV. Stark Effect

The atoms of hydrogen and helium are exceedingly sensitive to perturbations produced by electric fields. In a stellar atmosphere there are always present large numbers of free electrons and positive ions. When such charged particles are in the neighborhood of a radiating atom of H or of He they produce a change in the radiated wave-length. If only a single radiating atom is present its spectral line will be displaced in position. But if many atoms are present their spectral lines will not all coincide, because the distance to the nearest disturbing electron is not always the same. The result will be a broadened line.

The absorption coefficient must be computed by means of equation (12) in which the frequency function $\phi(\Delta\lambda)$ is that which applies to the Stark effect. A simple derivation of $\phi(\Delta\lambda)$ is due to Russell and Stewart. Let there be, on the average, one atom and M charged particles within a sphere of radius X. Then the probability that one charged particle happens to be within a distance x from a given atom is equal to the ratio of the volume of the two spheres

$$(4/3\pi x^3)/(4/3\pi X^3)\,.$$

Now, the probability that this will not be the case is, of course,

$$1 - x^3/X^3,$$

and the probability that not a single one of the M charged particles is within the sphere of radius x is

$$(1 - x^3/X^3)^M.$$

The probability that at least one of the M particles is within the smaller sphere, is

$$p = 1 - (1 - x^3/X^3)^M.$$

It can be readily verified that this expression is approximately

$$p \approx 1 - e^{-x^3M/X^3}$$

We next compute the probability that at least one of the M particles is within the shell of radius x and $x + dx$. For this purpose we differentiate the preceding expression

$$dp = e^{-(x/x_0)^3} d(x/x_0)^3,$$

where we have written $x_0 = X/M^{1/3}$.

This expression can be considered as the frequency function of different values of x. We wish to convert it into a frequency function of $\Delta\lambda$. To perform the transformation we recall that a field strength of $e/x_0^2$ produces a shift in the radiated line of $\Delta\lambda_0$. This means that the shift (for hydrogen) is proportional to the field strength, and that it is inversely proportional to $x^2$. It is clear that the desired frequency func-

tion is

$$e^{-(\Delta\lambda_0/\Delta\lambda)^{3/2}} d(\Delta\lambda_0/\Delta\lambda)^{3/2}. \tag{16}$$

The constant $\Delta\lambda_0$ measures the intensity of the Stark effect, and can be evaluated for any specific problem. Its significance is essentially similar to that of the constant $v_0$ or b in the Doppler effect problem.

The function (16) may also be written in the more usual form:

$$\phi(\Delta\lambda)\,d(\Delta\lambda) = \text{Const.}\ (\Delta\lambda_0^{3/2}/\Delta\lambda^{5/2})\ e^{-(\Delta\lambda_0/\Delta\lambda)^{3/2}} d(\Delta\lambda). \tag{17}$$

When $\Delta\lambda = 0$ this expression becomes $\infty \times 0$ but the limit for $\Delta\lambda \to 0$ is zero. As $\Delta\lambda$ increases $\phi(\Delta\lambda)$ rises steeply to a maximum, following which it gradually diminishes and slowly approaches zero for $\Delta\lambda = \infty$.

The hydrogen lines split up, in the Stark effect, into several symmetrically spaced components. Each component has a frequency distribution of the type of (17), with different values of $\Delta\lambda_0$. The combined absorption coefficient consists of the superposition of all curves.

We have already mentioned that if in (12) the function $\phi(\Delta\lambda)$ is much wider than the radiation damping function (10) then the shape of $\sigma^*$ will be essentially that of $\phi(\Delta\lambda)$.

The theory of Russell and Stewart has been elaborated by Verwej, who has applied it to the computation of the profiles of the hydrogen lines in various spectral types. However, the earlier results of Struve

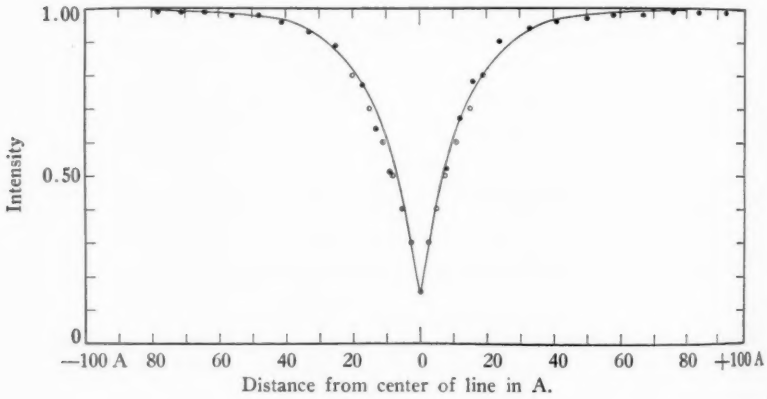



FIGURE 6
Profile of Hγ in Vega.

and Elvey were sufficient to show the general agreement of the theory with the observations. Fig. 6 shows the observed profile of $H_\gamma$ in Vega. The wings extend to 80 A on either side of the center. $H\delta$ is even wider, and merges with the wings of $H_\epsilon$.

The Balmer lines of hydrogen have the interesting property that alternate members have central, undisplaced components in the Stark effect, while the intermediate members have no central component. Thus

$H_\alpha$, $H_\gamma$, $H_\epsilon$, etc. have central components, while $H\beta$, $H\delta$, etc. have no central components. We should expect that since the function $\phi(\Delta\lambda)$ is 0 in the center the lines $H\beta$, $H\delta$, etc. would be bright in their centers, while $H_\alpha$, $H_\gamma$, $H_\epsilon$, etc. would be dark. Verwej's computations show that this center-effect should be present in very dense stars, such as the white dwarfs. But the phenomenon has not been observed. All lines seem to be dark in the center.

Another important effect is that of luminosity. The dwarfs are dense and the giants are tenuous. Accordingly, $\Delta\lambda_0$ will be large in dwarfs and small in giants. The hydrogen lines should be wide in dwarfs and

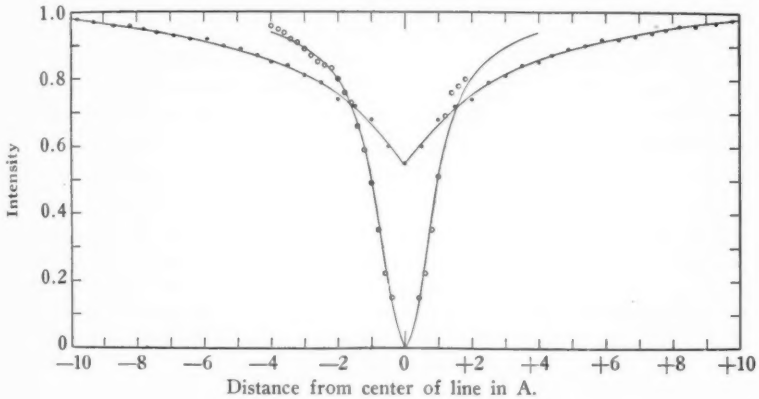



FIGURE 7

Profiles of $H\beta$ in $\epsilon$ Aurigae (circles) and $\gamma$ Pegasi (dots). The broadening is attributed to Stark effect.

narrow in giants. This is illustrated in Fig. 7. The narrow profile is that of the supergiant $\epsilon$ Aurigae; the wide profile belongs to the low-luminosity star $\gamma$ Pegasi.

The widths of the hydrogen lines are regarded as one of the most reliable criteria of absolute magnitude.

The Stark effect for ionized helium is essentially similar to that for hydrogen. Plate X shows the spectrum of the O star 10 Lacertae in which the lines He II 4542 and 4200 are appreciably broadened. Although for corresponding members the splitting in He II is only one-half of that in H, the quantum numbers for λλ 4542 and 4200 are so high that their Stark effect presumably exceeds that of all but the highest members of the Balmer series, where the lines are so crowded that they cannot be measured.

The line He II 4686 is only slightly broadened by Stark effect. In order to see the broadening of the lines λλ 4200 and 4542 in Plate X they must be compared with neighboring lines of similar intensity.

The Stark effect in He I is illustrated in Plate XI, showing the spec-

trum of γ Pegasi. All members of the two diffuse series of He I, namely ($2^1P - n^1D$) and ($2^3P - n^3D$) appear broadened, when they are compared with other lines of He I or of other elements. Notice, for example, the great widths of λλ 3872, 3927, 4009, 4026, 4144, etc. and compare them with λλ 3867, 3965, 4121, 4169, etc. This broadening is observed in all dwarfs of class B, which have sharp lines of other elements, such as Mg II, O II, Si III, etc. It is never observed in the supergiants.

The occurrence of forbidden lines of He I which violate the selection rules for the azimuthal quantum number is also attributed to the Stark effect. In Plate XI the line λ 4470 ($2^3P - 4^3P$) can be seen immediately to the violet of the permitted line λ 4472 ($2^3P - 4^3D$). Other forbidden lines have also been observed near λ 4388 and λ 4026.

The Stark effect in He I can be used to determine the average field strengths in the atmospheres of B stars, but the results are only moderately accurate.

## V. Collisional Damping

The He I lines of the diffuse series are particularly useful for a test of the theory of Stark effect. These lines do not, as a rule, split into symmetrical components as do the hydrogen lines. Thus the line λ 4472 shows components in the presence of electric fields which are all displaced toward the red side of the spectrum. The broadening should therefore be unsymmetrical, corresponding to one branch of the curve $\phi(\lambda)$. The problem is somewhat complicated because the forbidden line λ 4470 is broadened only toward the violet. At any rate the space of about 2A between the permitted and the forbidden line should not be filled with absorption.

Observations made at the Yerkes Observatory and also at Victoria prove conclusively that this space is not free from absorption. The profiles of the diffuse He I lines are much more symmetrical than the statistical theory of the Stark effect described in Section IV would lead us to expect.

Evidently, the simple statistical theory does not provide a sufficiently close picture of the phenomena in a stellar atmosphere. It must here be emphasized that there can be no doubt as to the existence of a Stark effect. This is attested to by the fact that only the members of the series ($2^1P - n^1D$) and ($2^3P - n^3D$) are broad and diffuse, while all other He I lines are sharp.

The trouble probably lies in the fact that in Section IV we tacitly assumed that during the process of radiation the chance arrangement of the atoms and electrons may be considered as static. If, during the process of radiation, appreciable changes take place in the distances between atoms and charged particles the statistical theory must be corrected.

In principle the theory must be worked out in the following manner. Suppose the normal frequency of the oscillation is $\nu_0$. Then the vibra-

tion is represented by a wave pulse

$$A \cos 2\pi\nu_0 t . \tag{18}$$

While the atom vibrates it is subject to disturbances in frequency resulting from charged particles. Hence $\nu$ varies as a function of time, and we must write for the vibration

$$A \cos 2\pi \int \nu(t)\,dt . \tag{19}$$

The distribution of intensities within the line is obtained by submitting (19) to a Fourier analysis. In other words, we represent (19) as a double Fourier integral and identify the coefficients of the terms $\cos \alpha t$ and $\sin \alpha t$ as the amplitudes of these terms.

This general problem has not yet been solved. But we possess the solution for two limiting cases. The first case corresponds to a very slow change of $\nu$ with the time. In that case we have, as can be easily proved, the result of the statistical theory of Section IV.

The other limiting case is that when during the process of radiation the phase differences accumulate to such an extent that

$$2\pi \int \Delta\nu\, dt \geqslant 1 . \tag{21}$$

This happens when an atom starts radiating with the normal frequency $\nu_0$. It is then disturbed by the passage of a charged particle and during the passage the phase differences accumulate. After the passage the atom continues radiating with frequency $\nu_0$, but its phase has been disturbed by $\int \Delta\nu\, dt$. This phenomenon may be interpreted as a complete interruption of the process of radiation during the passage, and this is analogous to a collision which interrupts the original wave train.

Now, the Fourier analysis of interrupted wave trains has been studied by Lorentz and the resulting expression for the absorption coefficient has the same form as that found for radiation damping:

$$\sigma_{\text{col}} = \frac{C^2\Gamma}{(\Gamma/2)^2 + 4\pi^2(\nu - \nu_0)^2} . \tag{22}$$

The constant $\Gamma$ is the collisional damping constant, which will depend upon the density of the gas, the concentration of charged particles, and the sensitivity of the line to Stark effect. Evidently, a dense atmosphere will bring the charged particles closer to the atoms, and great sensitivity to Stark effect will help accumulate the phase differences, so that an interruption in the wave train may occur ($\int 2\pi\Delta\nu\, dt \geqslant 1$).

Now, expression (22) is symmetrical with respect to $\nu_0$ and the broadening is, therefore, also symmetrical.

It is possible to show that the numerical value of $\Gamma$ greatly exceeds that of $\gamma$ for lines of H, He II, and He I. A rough estimate gives

$$\Gamma = 20\gamma_{\text{classe}} \tag{23}$$

for the line He I 4472.

Since the complete theory of equation (19) has not been worked out, we shall use a crude method for combining the two limiting cases. We

shall assume that we have a static distribution leading to a frequency distribution (17) and superposed over it a collisional broadening effect corresponding to (22). The result is obtained by means of an integration which is exactly analogous to formula (12). In Fig. 8 I have shown the results of a graphical integration, assuming an observational value

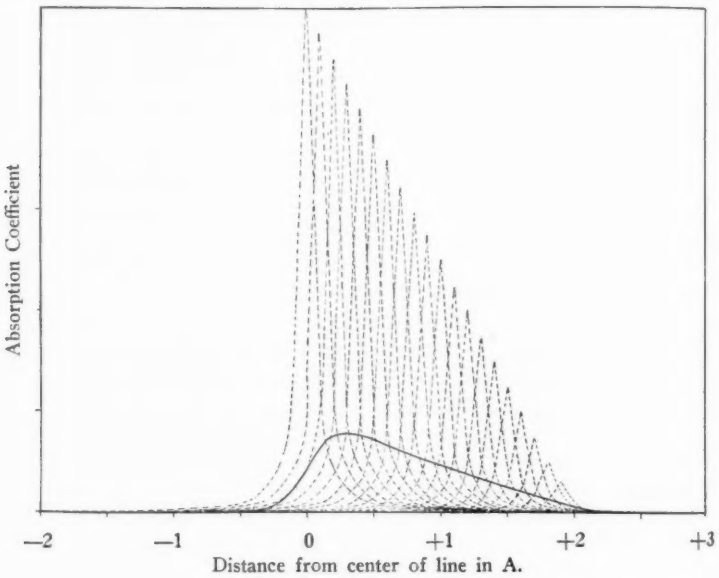



FIGURE 8

Absorption coefficient produced by statistical Stark effect and by the normal radiation damping The scale of the ordinates is arbitrary.

for $\gamma$ which corresponds to a sharp line produced largely by radiation damping. The function $\phi(\Delta\lambda)$ was assumed to be zero for all negative values of $\Delta\lambda$. It rises to a maximum at $\Delta\lambda = 0$ and decreases linearly, reaching zero at $\Delta\lambda = +2$A. This is a fairly good representation of (17). The shape of the narrow dotted curves gives the absorption coefficient corresponding to (1). The heavy line is the resulting absorption coefficient $\sigma^*$.

In Fig. 9 the function $\phi(\Delta\lambda)$ is the same, but the damping constant is $\Gamma = 10\gamma$. The heavy curve again represents $\sigma^*$. The scales of the figures are not the same, and this must be taken into consideration when a comparison is made. It is at once obvious that with the large $\Gamma$ the curve for $\sigma^*$ is much more symmetrical than with the small $\gamma$. Both curves are sufficiently low, even near the center, to represent with fair accuracy the profile of the resulting absorption line. To see this we recall that

$$I = I_0 e^{-\sigma^* NHf} . \tag{24}$$

Expand the exponential into a series:

$$I = I_0[1 - \sigma^* NHf + (\sigma^* NHf)^2/4 \ . \ . \ . \ ] . \tag{25}$$

If $\sigma^*$ is small the second and higher powers may be neglected and

$$I = I_0(1 - \sigma^* NHf) . \tag{26}$$

Hence the curve of $\sigma^*$ need only be inverted to give the profile of the line, provided NH is small. This was taken into account when the curves were made.

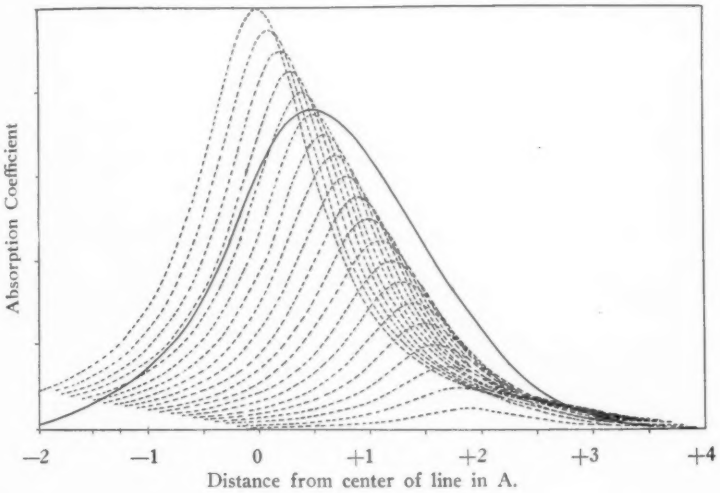



FIGURE 9

Absorption coefficient produced by the same amount of statistical Stark effect as in Fig. 8 and by a damping constant which is 10 times larger than in Fig. 8. The scale of the ordinates is arbitrary. Notice that the continuous curve for the absorption coefficient is nearly symmetrical.

The question might arise whether the He I lines are not so symmetrical that the limiting case of (22) is sufficient, without the integration according to (12). The answer is, I believe, negative. The damping constant enters into the numerator and the denominator of (1) and (22). The classical value of $\gamma$ is, as we have seen, very small. Hence a change of the damping constant by a factor of 10 or 20 affects the numerator directly. This cannot be distinguished from a corresponding increase in N, since the expression of the profile contains in the numerator of the exponent the product $C^1\gamma NHf$. The effect in the denominator is negligible when $\nu - \nu_0$ is large, that is, in the wings of the line. In the center, where $\nu = \nu_0$, the denominator is increased by $\gamma^2$ and $\sigma$ is decreased in the same proportion. But since the central value of $\sigma$ is always large

a change even by a factor of $\gamma^2$ makes relatively little difference in

$$I = I_0 e^{-\sigma N H f} .$$

Unless the damping constant is altered by an enormous amount, the resulting profile will tend to imitate one which is produced by a greater number of atoms, N. The observations disprove this: the diffuse He I lines are quite shallow, even in the center, and do not resemble profiles produced with varying N in equation (1). The marked decrease in the central absorption can only be accounted for if we combine the statistical theory with the collisional theory.

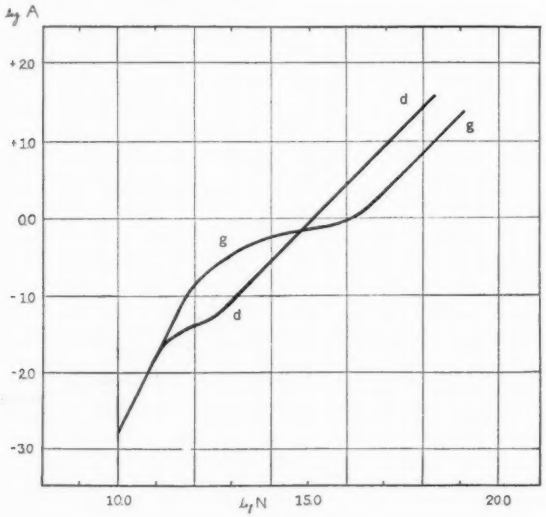



FIGURE 10

Curves of growth for a dwarf whose damping constant is increased by collisions but which has no appreciable turbulence, and for a giant whose damping constant is relatively small but which has large turbulent velocities.

The existence of an appreciable amount of collisional broadening in other lines has been demonstrated recently by Unsöld. For further details I must refer to his book. The subject is quite new and exceedingly fascinating. It is tempting to explain the enormous width of the Ca I line λ4227 in M-type dwarfs as an effect of collisional broadening. Similar effects should be looked for in the spectra of white dwarfs. It is possible that in these stars Γ becomes a hundred or even a thousand times larger than γ. This will produce shallow lines even without the integration of (12). Another interesting consequence of collisional damping is its effect upon the curve of growth. This is schematically shown in Fig. 10. The dwarf is assumed not to be subject to turbulence, the flat

part of the curve of growth being caused by thermal Doppler effect. Its damping constant $\Gamma$ is larger than $\gamma$. The giant is subject to turbulence, but its damping constant is $\gamma$. It is evident that great care must be exercised in the interpretation of the total absorptions!

*(To be continued)*

# The Sixtieth Meeting of the American Astronomical Society

By CURVIN H. GINGRICH

In order that it might be possible, for those who wished to do so, to attend both the International Astronomical Meetings in Stockholm and the American Astronomical Society Meetings in Ann Arbor, the time for holding the latter was one week later than the customary annual schedule, the dates this year being September 14-17. There were several members who availed themselves of the opportunity afforded by this arrangement of schedule. Moreover, because of the relatively central location of the place for the Society Meetings the attendance was rather larger than usual. Although there were only eighty-six names of persons who had signified their intention of attending, there were one hundred sixteen persons in the group for the photograph and there were a few others who were busy elsewhere at the time. It would seem that the official register which circulated continuously during the sessions might be the most reliable source for statistics of this kind, but its reliability was somewhat impugned by the discovery that certain absent-minded professors and certain zealous research workers did not hesitate to sign each time the register reached them!

The various individuals and parties converged upon Ann Arbor on Wednesday evening, September 14. They were cordially greeted at the headquarters which were at the Michigan Union, and the reception seemed warmer and was the more appreciated by those who had traveled through a chilly rain to reach their destination. The council was in session during the evening.

The first general session was scheduled to be opened at nine o'clock on Thursday morning in the smaller auditorium in the recently completed building known as the Horace H. Rackham School of Graduate Studies. The elegant and artistic appointments of this building immediately arrested the attention of all of the astronomers as they came to the building and continued to be much admired and enjoyed during the meeting. The session was called to order by the president of the Society, Dr. Robert G. Aitken. Dr. Heber D. Curtis, director of the Observatories of the University of Michigan, and, in a sense, the host of the meeting, was presented and in turn introduced Dr. Clarence Stone Yoakum, dean of the graduate school, who, in the name of the president

of the University, extended the hospitality of the University in general and of the Rackham building in particular to the members and friends of the Society. It was entirely fitting that Dr. Yoakum should be chosen to do this, for, in his capacity as dean of the graduate school, heavy duties in connection with the erection of the building and with the administration of the large Rackham fund devolved upon him. After an appropriate response by Dr. Aitken the meeting was auspiciously under way.

The chairman requested the secretary to read the names of the members deceased within the year. They were:

| | |
|---|---|
| STORRS B. BARRETT | GEORGE E. HALE |
| WALTER E. BERNHEIMER | JAKOB KUNZ |
| ERNEST W. BROWN | RAYMOND S. PATTON |
| WILLIAM W. CAMPBELL | FRANCIS G. PEASE |
| VERA M. GUSHEE | WILLIAM H. PICKERING |

The audience stood during a period of silence as a token of respect to the memory of these members who had departed this life.

The remainder of the morning session, as well as the afternoon session of this day and a morning and an afternoon session of Friday, was used in the presentation of papers. In all, forty-three papers were read and discussed. Abstracts of these papers, as formerly, will appear in the Publications of the Society, and therefore the technicalities of these papers will be omitted here.

The beginning of the afternoon session on Friday was taken up with the annual business items. The report of the tellers showed that officers had been elected as follows:

Vice-President ..... Philip Fox
Secretary ..... John C. Duncan
Treasurer ..... Frank C. Jordan
Councilors—
Alice H. Farnsworth, Donald H. Menzel, J. H. Pitman
Representative of Society in the Division of Physical Sciences of the National Research Council ..... W. H. Wright
Nominating Committee—
Henry N. Russell, *Chairman*, Otto Struve, J. J. Nassau

The report of the secretary showed, among other things, that

1. the sixteen following named persons had been elected by the council to membership in the Society:
Dr. Claude M. Anderson, Jr., Leander McCormick Observatory.
Paul R. Annear, Lawton Fellow in Astronomy, University of Michigan.
Professor Robert W. Boreman, Assistant Professor of Physics, Carnegie Institute of Technology.
Mr. Claude B. Carpenter, A.A.V.S.O. Observer of Variable Stars, 34624 Chestnut St., Wayne, Michigan.
Gerald M. Clemence, Assistant Astronomer, U. S. Naval Observatory.
Dr. Willi M. Cohn, University of California, Berkeley.
Miss Dorothy N. Davis, Instructor in Astronomy, Vassar College.
Edwin Ebbinghausen, Assistant, Yerkes Observatory.
Mr. Herbert R. J. Grosch, Rackham Fellow, Univerity of Michigan.

Mr. Henry Hemmendinger, Thaw Fellow in Astronomy, Princeton University.
Mr. William W. A. Johnson, Graduate Student, Harvard College Observatory.
Mr. Richard F. Kinnaird, Research Assistant, Dearborn.
Mr. Neil C. McMath, Honorary Curator of Observatories of the University of Michigan, 58 Haltimer St., River Rouge, Michigan.
Mr. Lloyd C. Oleson, Graduate Student, Yale University.
Professor H. P. Robertson, Professor of Mathematical Physics, Princeton University.
Mr. F. Bradshaw Wood, Graduate Student, Princeton University.

2. the membership of the Society now is 609.

3. the meeting in December, 1938, will be held at Columbia University and the one in the summer of 1939 at Berkeley, California.

4. Dr. C. H. Smiley had been appointed as Assistant Secretary, and would be in charge of the December meeting.

The treasurer stated that the Society had received as a bequest from the late Ernest W. Brown the sum of five thousand dollars as the beginning of a fund to establish a Journal of the Society, for the purpose of publishing reports of researches somewhat more extensively than the abstracts as they are now being published. A bequest of one thousand dollars from the same estate was made to the Hollerith Computing Bureau, Columbia University.

After the completion of the reading of papers at this session Professor Philip Fox happily expressed the sentiment of the entire group in extending to all who had contributed to the success of the meeting the hearty thanks of the Society. The remarks by Professor Fox were enthusiastically and unanimously endorsed by a rising vote. Thus the official part of the meeting was concluded.

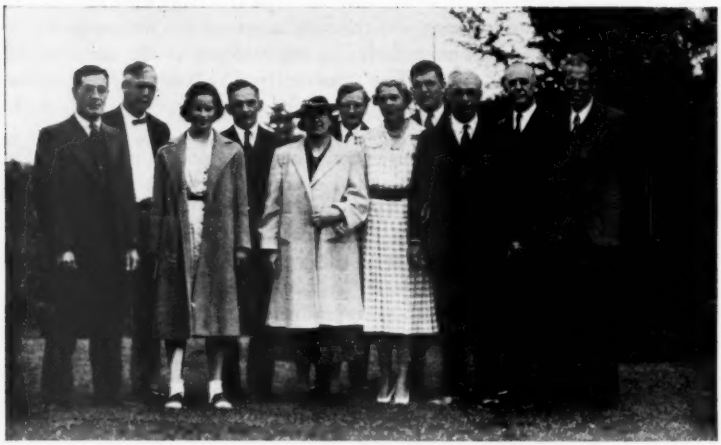
The report of the meeting, however, does not end with that. Dr. Curtis and his associates had planned events of interest for all in the hours which were not occupied by formal sessions. The group photograph was taken on the steps of the Rackham building at noon of the first day and is included as a part of this report. This was followed by a complimentary luncheon tendered by Mrs. Heber D. Curtis and the women of the observatory staff to the ladies in attendance. This event was held in the Ethel Fountain Hussey Room, a name replete with astronomical associations at this university. It was thoroughly enjoyed by all who were privileged to participate. The evening hours of the first day were devoted to a personally conducted tour, first to the students' observatory on the fifth floor of Angel Hall, thence to the physics building to see the cyclotron, the modern apparatus used in the study of the structure of the atom, thence to the Observatory where the several telescopes and other equipment were exhibited. All were eager to see the disk of glass, recently moved from the Corning Glass Works to a suitable shelter on the Observatory grounds. This disk will ultimately furnish a mirror of more than ninety inches in diameter for a telescope the location for which some distance from Ann Arbor has already been secured. The itinerary finally led through the library into the Observatory house where Mrs. Curtis and the other women of the Observatory staff tend-

ered a reception with concomitant refreshments—a fitting and much appreciated climax to an evening of instruction and enjoyment.

The Society dinner was held on Friday evening in the spacious rooms of the Michigan Union. Immediately following the dinner two rare and highly prized volumes were presented to the Library of the Observatory of the University. They were a copy of the first edition of Copernicus, published in Nuremberg in 1543, and a copy of the first edition of Galileo bearing the date of 1632. Also an original letter from Galileo to Prince de Medici, relative to his newly constructed telescope and discoveries by it, was transmitted. The letter was neatly framed with a translation of it included. The presentation of these items was accompanied by the following citation:

> These books and this letter, from the collection of the late Tracy W. McGregor, are given by the McGregor Fund to the University of Michigan for its astronomical libraries in special recognition of the services to astronomy by Professor Heber D. Curtis and as a mark of the esteem felt for him by Mr. McGregor and by the Trustees of the McGregor Fund.

Following this ceremony the party moved to the room in the Union known as the Pendleton Library and there spent the rest of the evening in conversation and reminiscence.



STAFF OF THE MCMATH-HULBERT OBSERVATORY

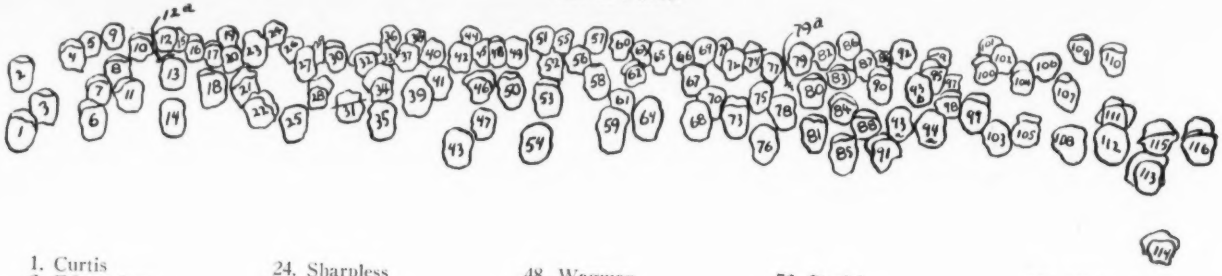
Left to right, Neil C. McMath, Edison Pettit, Miss Madeline McMath, H. E. Sawyer, Mrs. Edison Pettit, Keivin Burns, Mrs. Robert R. McMath, George Malesky, Robert R. McMath, Henry S. Hulbert, S. L. Boothroyd.

The following morning nearly one hundred persons started early for Lake Angelus, some by automobile and others by chartered bus. This was in response to an invitation from the McMath-Hulbert Observatory now well known among astronomers. It was regarded as an exceptional

PLATE XII

SIXTIETH MEETING OF THE AMERICAN ASTRONOMICAL SOCIETY, ANN ARBOR, MICHIGAN, SEPTEMBER 14-17, 1938.

Key to Plate



1. Curtis
2. Edmondson
3. Kiess
4. Fecker
5. Miss Gamble
6. Burns
7. Miss Van Biesbroeck
8. Van Biesbroeck
9. Mrs. Duncan
10. Mrs. Sharpless
11. Rufus
12. Gingrich
12a. Miss Fecker
13. C. M. Huffer
14. Boothroyd
15. Mrs. Smiley
16. Miss Gingrich
17. Mrs. Gingrich
18. Baldwin
19. Bobrovnikoff
20. Yowell
21. Miss Northcott
22. Miss Marjorie Williams
23. Wurm
24. Sharpless
25. Slocum
26. Miss Barney
27. W. E. Anderson
28. Mrs. Chant
29. F. P. Scott
30. Henyey
31. Mrs. Hogg
32. Mrs. Wagman
33. Mrs. Littell
34. Miss Patterson
35. Carpenter
36. Stokley
37. W. W. Morgan
38. Hoffman
39. Moffitt
40. Stearns
41. H. P. Robertson
42. H. R. Morgan
43. Chant
44. Robinson
45. Littell
46. Mrs. Greenstein
47. Mohler
48. Wagman
49. Herget
50. Greenstein
51. Smiley
52. Whipple
53. Perkin
54. J. A. Miller
55. R. T. Fox
56. R. C. Williams
57. Cogshall
58. Norman
59. Jordan
60. Annear
61. Calder
62. Mrs. R. C. Williams
63. O'Keefe
64. Mehlin
65. Wisselink
66. Cuffey
67. N. L. Pierce
68. Aitken
69. Nassau
70. Rumrill
71. Keenan
72. Daniel
73. Marshall
74. Mrs. Nassau
75. Mrs. N. L. Pierce
76. Plaskett
77. Wares
78. Aldrich
79. Ellis
79a. Mrs. Carpenter and Roger
80. Hetzler
81. Grosch
82. Maier
83. Miss Bennett
84. Mrs. McLaughlin
85. McLaughlin
86. Goedicke
87. Hynek
88. Mrs. R. H. Curtiss
89. Chandrasekhar
90. Dustheimer
91. Mrs. H. D. Curtis
92. Ford
93a. Miss Yü
93b. Hibbard
94. Duncan
95. Mrs. Hynek
96. Mrs. Gaposchkin
97. Mrs. Slocum
98. Mrs. Boothroyd
99. Hesthal
100. Mrs. Link
101. Struve
102. Cherrington
103. Philip Fox
104. Mrs. Cherrington
105. Mrs. Losh
106. Link
107. Heard
108. W. H. White
109. Ebbighausen
110. J. D. Williams
111. Mrs. Heard
112. Pawling
113. Mrs. Goedicke
114. Sally Goedicke
115. Miss Losh
116. Gaposchkin

privilege to see the equipment which in the last few years has produced such novel results in astronomical study. As this observatory and its work have been described in other places it is unnecessary to repeat the description here. The accompanying photograph, however, is new, having been made at the time of the visitation here referred to.

The hours of the morning which remained after arriving at Lake Angelus were pleasantly and profitably spent in going from building to building, and finding in each one an interesting and intelligent delineation of the work being done. After the tour of astronomical domes was completed a path very invitingly led across the lawn through avenues of flowers and shrubbery to the large residence on the shore of Lake Angelus. Here, in the basement recreation room, moving pictures of the turbulent solar surface were continuously shown. The accuracy with which the rising and falling of solar prominences were depicted was most convincing of their reality. The restless, seething photosphere was vividly illustrated and the distant sun seemed to be brought quite near.

When the time for luncheon arrived the guests were directed to the bountifully supplied dining room from which they emerged laden with all that could be desired in a physical way to complement the intellectual and aesthetic feast already enjoyed. They were grouped about small tables in the spacious living rooms and halls, and the congeniality of the astronomical fraternity was again afforded an opportunity of expression.

After a leisurely luncheon farewells were exchanged and hearty thanks extended to Mrs. McMath and the others who had made the final event such a notable success, after which the several parties reluctantly left the enticing surroundings and began their journeys homeward.

The sixtieth meeting was a thing of the past but the pleasant memories engendered by it will continue to be in the present for some time to come.

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## ETERNAL WHY

A nothingness that fetters sight
To many distant points of light;
And stretches high—

A void that, when the day is done,
Ushers in stars one by one;
And draws the eye . . .

Patterns all in brilliant chorus
Each constellation passes o'er us;—
A wondrous sky . . .

We on this whirling, puny globe,
Though deep we think and hard we probe
And hard we try;
This darkness, soothing, wandering free,
(Yet seething with activity)
Is one black why!

EUGENE GINSBERG.

288 Graham Ave., Paterson, N. J.

# Limits of Umbral Runs in Lunar Saros Series

By ALEXANDER POGO

According to Oppolzer's *Canon der Finsternisse*,[1] the magnitude of the eclipse of 1939 October 28 will be $12^{z}.1$ (equivalent to 1.01, the diameter of the moon being = 1); according to the *American Ephemeris and Nautical Almanac*, the magnitude of this eclipse will be 0.992; in other words, the *Canon* predicts a shallow total eclipse, the almanacs predict a deep partial eclipse. Whenever Oppolzer's magnitude is near $12^{z}.0$, the lunar eclipse may be either total or partial; a consultation of a nautical almanac or a computation with the aid of Neugebauer's ecliptic tables[2] will, as a rule, permit us to classify such an eclipse either as total or as partial; fortunately, all these eclipses are listed in the *Canon* and can be easily recognized by a mere inspection of the column of magnitudes; we shall not deal with them in the present paper.

Whenever Oppolzer's magnitude is near $0^{z}.0$, the lunar eclipse may be either umbral or penumbral; some shallow partial lunar eclipses have been omitted from the *Canon*, because the computations yielded a negative magnitude; on the other hand, several deep penumbral lunar eclipses are listed in the *Canon* as small partial eclipses. A systematic investigation has been made of the limits of the umbral runs of the lunar saros series included in the *Canon;* the results were published in "Additions and Corrections to Oppolzer's *Canon der Mondfinsternisse*."[3] The table of additions contained 19 umbral (magn., +0.01 or more) and 15 "possibly umbral" (magn. = 0.00) lunar eclipses not listed in the *Canon;* the table of corrections contained 21 penumbral (magn., —0.01 or less) and 14 "possibly penumbral" (magn. = 0.00) lunar eclipses listed in the *Canon*. Both the table of additions and the table of corrections could have been expanded; the magnitudes computed with the aid of Neugebauer's ecliptic tables may be considered as correct within 0.03 of a unit; the table of additions could, therefore, have been expanded by including, among the "possibly umbral" eclipses, not only those of magnitude 0.00 but also eclipses with computed magnitudes down to —0.03; on the other hand, the table of corrections could have been expanded by considering as "possibly penumbral" eclipses not only the eclipses of magnitude 0.00 but also those with computed magnitudes up to +0.03. For the purposes of the paper published in the *Astronomical Journal*, as well as for the purposes of the present paper, it was considered desirable to regard 0.00 as the limiting doubtful magnitude. The reader must keep in mind that a small positive magnitude, amounting to +0.03 or less, can be used as a computational criterion for classifying an eclipse as

[1] *Denkschriften d. Akademie*, math.-naturw. Cl., Bd. 52, Wien 1887.
[2] Astronomische Chronologie, Berlin 1929.
[3] *Astronomical Journal*, 47, 45-48, 1938.

umbral, while the actual phenomenon may be a mere contact of the moon with the physical umbra or even a deep penumbral eclipse; similarly, a computed small negative magnitude of from —0.01 to —0.03, while classifying an eclipse as penumbral, may correspond, in reality, to a contact of the moon with the physical umbra or even to a shallow partial eclipse; the lunar saros series L10 and L48, discussed below, offer a practical application of these theoretical remarks.

TABLE I

REVISED LIMITS OF COMPLETE UMBRAL RUNS OF LUNAR SAROS SERIES

| Lunar saros series | U′ | Oppolzer's first partial | Oppolzer's last partial | U″ | Opp. *n* | Rev. *n* |
|---|---|---|---|---|---|---|
| L6 | 348 Oct 23 | 366 Nov 4 | 1304 May 20 | 1286 May 9 | 53 | 53 |
| L12 | | 475 Jul 4 | *1304 Nov 13* | 1286 Nov 2 | 47 | 46 |
| L23 | —263 Mar 7 | —281 Feb 25 | 512 Jne 15 | | 45 | 44 |
| L29 | | —245 Sep 11 | 765 May 9 | 747 Apr 29 | 57 | 56 |
| L30 | *873 Aug 12* | 891 Aug 23 | 1883 Apr 22 | | 56 | 57 |
| L36 | | 1126 Jul 6 | 2082 Feb 13 | 2064 Feb 2 | 54 | 53 |
| L40 | —983 May 15 | —1001 May 5 | —280 Jul 10 | | 41 | 40 |
| L46 | —838 Feb 3 | —856 Jan 24 | —63 May 14 | | 45 | 44 |
| L52 | —820 Aug 8 | —838 Jul 29 | 208 Apr 18 | | 59 | 58 |
| L64 | | —386 Apr 15 | *371 Jul 14* | 353 Jul 3 | 43 | 42 |
| L71 | 804 Oct 22 | 822 Nov 2 | 1760 May 29 | | 53 | 54 |
| L76 | —169 Aug 13 | *—187 Aug 1* | 787 Mar 8 | | 55 | 54 |
| L81 | —1124 Jne 12 | —1142 Jne 2 | —385 Aug 30 | | 43 | 42 |
| L82 | 12 May 24 | 30 Jne 4 | 823 Sep 24 | 805 Sep 12 | 45 | 45 |
| L87 | —925 Apr 5 | —943 Mar 25 | —204 Jne 11 | *—186 Jne 22* | 42 | 42 |
| L94 | 247 Oct 2 | 265 Oct 12 | 1203 Apr 27 | | 53 | 54 |
| L99 | | —726 Jul 22 | 266 Mar 8 | 248 Feb 26 | 56 | 55 |
| L100 | | 428 Jul 12 | *1456 Mar 22* | 1438 Mar 11 | 58 | 57 |
| L111 | —274 Apr 7 | *—292 Mar 26* | 483 Jul 6 | | 44 | 43 |
| L118 | | 880 Sep 22 | 1890 Jne 3 | 1872 May 22 | 57 | 56 |
| L123 | | —129 Jne 22 | 881 Feb 18 | 863 Feb 7 | 57 | 56 |
| L124 | 1097 Jul 27 | 1115 Aug 7 | 1890 Nov 26 | | 44 | 45 |
| L128 | —1066 May 3 | —1084 Apr 22 | —327 Jul 20 | | 43 | 42 |
| L134 | —849 Mar 6 | —867 Feb 22 | —74 Jne 14 | | 45 | 44 |
| L140 | —813 Sep 21 | *—831 Sep 10* | 143 Apr 17 | | 55 | 54 |
| L146 | | —668 Jne 10 | 197 Nov 12 | 179 Nov 2 | 49 | 48 |
| L147 | | 558 Jul 16 | 1514 Feb 9 | 1496 Jan 30 | 54 | 53 |
| L158 | —162 Mar 30 | *—180 Mar 19* | 541 May 25 | | 41 | 40 |
| L170 | | 1 Jne 24 | 957 Jan 18 | 920 Dec 28 | 54 | 52 |
| L175 | —972 Apr 13 | —990 Apr 3 | —197 Jul 23 | | 45 | 44 |
| L177 | 1408 May 10 | *1390 Apr 29* | 2147 Aug 11 | | 43 | 42 |
| L182 | 236 Oct 31 | 254 Nov 12 | 1192 May 28 | | 53 | 54 |
| L193 | | —556 Jne 2 | 273 Oct 13 | 255 Oct 3 | 47 | 46 |
| L200 | 851 Apr 19 | *833 Apr 8* | 1608 Jul 27 | | 44 | 43 |
| L205 | —375 Sep 8 | —357 Sep 19 | 635 May 7 | | 56 | 57 |
| L206 | 1050 Feb 9 | 1068 Feb 21 | 1825 Jne 1 | | 43 | 44 |
| L211 | | —140 Jul 22 | *888 Mar 31* | 870 Mar 21 | 58 | 57 |
| L216 | | —1113 May 12 | *—320 Aug 31* | —338 Aug 21 | 45 | 44 |

In a previous paper, "Lunar Saros Series,"[4] the number of umbral runs complete within the limits of the *Canon* was given as 80; now this number may be changed to 81. The 80 series with complete umbral runs did not include the lunar saros series L177; Oppolzer's magnitude, $1^{z}.4$, of the partial eclipse of 2147 August 11 made the umbral or penumbral nature of the next eclipse of the series uncertain; the *Canon* does not list lunar eclipses occurring after A.D. 2163. Computations show that the eclipse of 2165 August 21 will reach the magnitude —0.02; Oppolzer's eclipse of 2147 August 11 may, therefore, be considered as the last partial eclipse of series L177, and the umbral run of this saros series as complete within the limits of the *Canon*.

Of the 81 lunar saros series whose umbral runs begin and end within the limits of Oppolzer's *Canon*, 43 saros series remained unaffected by the investigation of the magnitudes of the eclipses near the limits of the umbral runs. The 38 revised saros series are listed in Table I. The double column in the center of the table gives, for these 38 series, the first and the last umbral eclipse, according to Oppolzer. The columns U′ and U″ give, respectively, the revised date of the first and of the last umbral eclipse of the series. Italicized dates indicate eclipses which, according to the tables published in the *Astronomical Journal*, have a computed magnitude 0.00 and may, therefore, be either shallow umbral or deep penumbral eclipses; in the case of the 13 saros series which contain italicized dates, the actual date of the first or of the last umbral eclipse must be considered as uncertain. The last two columns of Table I give the number of eclipses in the umbral run, according to Oppolzer's *Canon* and according to our revision, respectively.

A comparison of the numbers listed in the last two columns of Table I reveals that in the case of 3 saros series—L6, L82, and L87—the revision left the number of umbral eclipses in the run unchanged, although the italicized date in series L87 indicates that the umbral run may have consisted of 41 eclipses, as against Oppolzer's 42; in the case of 7 saros series, the revision increased the number of umbral eclipses in the run by one; in the case of 27 saros series, the revision decreased the number of umbral eclipses in the run by one, and in one case—L170— by two eclipses.

Table I shows that the revision has changed the *dates* of the limiting umbral eclipses in the case of at least 25 saros series, and that the *number* of eclipses in the umbral runs has been changed, by the revision, in the case of at least 24 saros series. The diagram reproduced in Figure 1 shows, at a glance, the influence of the revision on the length of the 81 complete umbral runs.

There are, in the *Canon*, 29 lunar saros series with incomplete ("beheaded") umbral runs which begin before 1207 B.C.; the revision of magnitudes affects 11 of these "beheaded" umbral runs. Similarly,

[4] Popular Astronomy, **43**, 207-213, 1935.

there are, in the *Canon*, 29 lunar saros series with incomplete ("tailless") umbral runs which end after A.D. 2163; the revision of magnitudes affects 6 of these "tailless" umbral runs. In the case of 15 of these 17 incomplete umbral runs, the revision introduced changes similar to those of Table I, *i.e.*, the addition or the elimination of one or, exceptionally, of two eclipses; the remaining two revised incomplete runs belong to the series L10 and L48 discussed below.

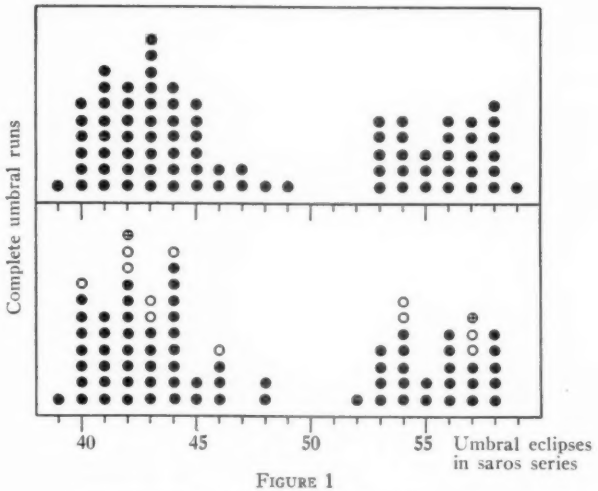


FIGURE 1

DISTRIBUTION OF SHORT AND LONG UMBRAL RUNS IN LUNAR SAROS SERIES

Top: Oppolzer's data
Bottom: Revised data

Open circles represent the saros series L12, L64, L76, L100, L111, L140, L158, L177, L200, L211, and L216. Some of these circles may belong to the neighboring columns on their right.

Crossed circles represent the saros series L30 and L87. These circles may belong to the neighboring columns on their left.

The lunar saros series L10 consisted of 74 or, possibly, of 73 eclipses, if the full moon of —2049 March 13 failed to encroach on the elusive fringe of the penumbral cone. The initial penumbral run consisted of 9 or, possibly, of 8 eclipses, and came to an end in —1905, on June 8. The umbral run of the lunar saros series L10 began with the partial eclipse of —1887 June 18; it is impossible to give the date on which this umbral run came to an end. According to Oppolzer's *Canon*, the last partial eclipse of the series occurred in —1112, on September 25. Table II shows, however, that between —1094 October 7 and —968 December

21 the computed magnitudes of the eclipses belonging to the saros series L10 remained within 0.03 of the magnitude zero. In other words, the computations do not permit us to decide whether these eclipses were shallow partial eclipses, mere contacts of the full moon with the physical umbra, or deep penumbral eclipses. Three of these critical eclipses are listed as small partial eclipses, of magnitude $0^{z}.1$, in Neugebauer and Hiller's *Spezieller Kanon der Mondfinsternisse für Vorderasien und Ägypten von 3450 bis 1 v. Chr.*;[5] the eclipse of —1076 October 17 was not visible within the territory covered by Neugebauer and Hiller's

TABLE II

CRITICAL ECLIPSES OF THE LUNAR SAROS SERIES L10

| No. | Date | Magn. | $\lambda_s$ | $\phi_s$ | N.-H. | Opp. |
|---|---|---|---|---|---|---|
| 1 | —2049 Mar 13.69 | —1.04 | +114° | +10° | | |
| 2 | —2031 Mar 24.01 | —0.91 | — 2 | + 6 | | |
| .. | ..... | ..... | ..... | .... | | |
| 9 | —1905 Jne 8.16 | —0.05 | — 57 | —20 | | |
| 10 | —1887 Jne 18.46 | +0.09 | —166 | —22 | | |
| .. | ..... | ..... | ..... | .... | | |
| 53 | —1112 Sep 25.75 | +0.04 | + 89 | — 3 | 0.6 | 0.2 |
| 54 | —1094 Oct 7.08 | +0.01 | — 32 | + 1 | 0.1 | |
| 55 | —1076 Oct 17.41 | +0.01 | —150 | + 6 | | |
| 56 | —1058 Oct 28.75 | 0.00 | + 87 | +10 | 0.1 | |
| 57 | —1040 Nov 8.09 | —0.02 | — 35 | +14 | | |
| 58 | —1022 Nov 19.43 | —0.03 | —159 | +18 | | |
| 59 | —1004 Nov 29.77 | +0.01 | + 78 | +20 | 0.1 | |
| 60 | — 986 Dec 11.11 | 0.00 | — 44 | +22 | | |
| 61 | — 968 Dec 21.46 | 0.00 | —166 | +23 | | |
| 62 | — 949 Jan 1.79 | —0.04 | + 74 | +24 | | |
| .. | ..... | ..... | ..... | .... | | |
| 74 | — 733 May 11.51 | —1.02 | +174 | —15 | | |

*Spezieller Kanon*. On the basis of Table II, the number of eclipses in the umbral run of the saros series L10 must have been comprised between 45 and 52; on the basis of Figure 1, we may restrict the number of umbral eclipses in the lunar saros series L10 to 45, 46, 47, 48, or 49, if the umbral run was short, and we must admit the possibility of 52 eclipses, if the umbral run was long; in other words, if the umbral run of series L10 did not come to an end on or before —1022 November 19, then it is probable that it lasted until —968 December 21.

The lunar saros series L48 will consist of 73 or, possibly, of 72 eclipses, if the full moon of A.D. 2443 September 9 should fail to touch the penumbral cone. The terminal penumbral run will consist of 7 or, possibly, of 6 eclipses; the number of penumbral terminal eclipses may reach 8, if the full moon of 2317 June 25 should fail to encroach on the umbral cone. It is impossible to give the date of the first umbral eclipse of the saros series L48. According to Oppolzer's data, the first umbral eclipse of the series occurred in 1470, on January 17. Table III shows, however, that between 1361 November 13 and 1488 January 28 the com-

[5] *Astronomische Abhandlungen*. Ergänzungshefte zu den *Astronomischen Nachrichten*, Bd. 9, Nr. 2, Kiel 1934.

puted magnitudes of the eclipses belonging to the saros series L48 remained within 0.03 of the magnitude zero; it is impossible to decide, on the basis of these computed magnitudes, whether these eclipses were deep penumbral eclipses, mere contacts of the full moon with the physical umbra, or shallow partial eclipses. On the basis of Table III, the number of umbral eclipses in the saros series L48 may be as low as 46, if the umbral run should be counted between 1488 and 2299, or as high as 54, if the umbral run should be counted between 1361 and 2317; on the basis of Figure 1, however, we may omit the numbers 50 and 51; if the umbral run of the lunar saros series L48 will come to an end in

TABLE III

CRITICAL ECLIPSES OF THE LUNAR SAROS SERIES L48

| No. | Date | Magn. | Opp. |
|---|---|---|---|
| 1 | 1145 Jul 6 | —0.98 | |
| .. | ..... | ..... | |
| 13 | 1361 Nov 13 | —0.03 | |
| 14 | 1379 Nov 24 | —0.03 | |
| 15 | 1397 Dec 4 | —0.01 | |
| 16 | 1415 Dec 16 | 0.00 | |
| 17 | 1433 Dec 26 | 0.00 | |
| 18 | 1452 Jan 7 | 0.00 | |
| 19 | 1470 Jan 17 | 0.00 | 0.1 |
| 20 | 1488 Jan 28 | +0.03 | 0.6 |
| .. | ..... | ..... | |
| 66 | 2317 Jne 25 | +0.01 | |
| 67 | 2335 Jul 7 | —0.15 | |
| .. | ..... | ..... | |
| 72 | 2425 Aug 29 | —0.91 | |
| 73 | 2443 Sep 9 | —1.05 | |

2317, then it must have started not later than in 1397, if the run will be a long one, and it could not have started earlier than in 1452, if the run will be a short one; if the umbral run will come to an end in 2299, then the limiting starting dates are 1379 and 1433, respectively; the umbral run could not have started in 1415.

The total lunar eclipse of 1938 November 7, visible in America, belongs to the saros series L48. It will be the 45th eclipse of the saros series, but it is impossible to say how many umbral eclipses of the series have preceded it—the eclipse of 1938 November 7 may be the 26th to 29th or the 31st to 33rd umbral eclipse of the saros series L48.

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# Section on Astronomy (D) of the A.A.A.S. in Ottawa

(From Report by Harlan T. Stetson, Secretary)

The Section on Astronomy (D) held three sessions during the days from June 27 to July 2, inclusive, all of which were joint sessions with the Royal Astronomical Society of Canada. Thirty papers were presented including four by invitation, comprising the symposium on ozone. The Tuesday and Wednesday morning sessions were held at the Dominion Observatory through the courtesy of its director, Dr. R. Meldrum Stewart. The Thursday morning session was held at the Masonic Temple and was conducted as a symposium on atmospheric ozone, two participants representing the United States and two the Dominion of Canada.

Dr. W. E. Harper, Director of the Dominion Astrophysical Observatory, opened the program with an historical summary of fifty years of astronomy in Canada. Dr. Harper showed the remarkable progress that had been made in the Dominion from the early days, when a small transit was the only official observing instrument, to the present day, in which Canada holds two of the world's largest reflectors, the 72-inch at Victoria and the 74-inch at the David Dunlap Observatory. The technical papers covered a wide distribution of subject matter in astronomy. Several papers on the program dealt with the sun and related phenomena. The near maximum of the present sunspot cycle, probably just passed, brought interesting discussion of terrestrial phenomena related to the solar cycle and emphasized the growing concern of interest in solar problems to related sciences. The discussion of sunspot influence on tree growth in Canada was discussed by John O'Connor of the Dominion Observatory who pointed out that meteorological differences, apparently indicated by the behavior of tree growth, persisted between coastal and interior areas, in general correlations between tree growth and sunspots being of opposite sign in the interior and coastal forests. Discussion brought out the futility of averaging indiscriminately meteorological or other terrestrial data in studies of solar effects without recognition of these regional influences. Other effects of the sunspot cycle were discussed by Dr. De Lury of the Dominion Observatory. A statistical study of the distribution of sunspots in longitude was presented by Dr. Losh of the University of Michigan Observatory.

A paper of human interest bearing on the accuracy of positions determined in polar explorations came from Dr. Heber D. Curtis, Director of the Michigan Observatory, who, from a re-computation of original data, presented evidence that, even after considering any reasonable allowable errors, Commodore Peary's observations in 1906 showed that

he passed within three miles and probably within .8 of a mile of the pole if not actually crossing the earth's axis.

A spectroscopic attempt to evaluate the green colored areas of Mars was described by Dr. Millman of the David Dunlap Observatory, who presented strong evidence that the character of the light from the darker Martian areas could not reasonably be interpreted as reflection from chlorophyll, thus weakening somewhat the support for vegetation on that planet, at least of the kind existing on the earth.

The symposium on atmospheric ozone and the measurement of ultra-violet and solar radiation, arranged and conducted by Dr. Brian O'Brien of the University of Rochester, aroused much interest in many borderline problems including astronomy, meteorology, and biophysics. Dr. B. Haurwitz of the Canadian Meteorological Service discussed the general problem of ozone as a constituent of the atmosphere; Dr. E. H. Gowan of the University of Alberta discoursed on ozone temperatures under radiative equilibrium; Dr. Chaim Pekeris of the Massachusetts Institute of Technology gave a clear exposition of the distribution of atmosphere ozone and discussed its relation to meteorology as far as present data will allow. The symposium was closed by Dr. Brian O'Brien who most ably summarized existing knowledge of atmospheric ozone as determined from measurements of ultra-violet solar radiation. The technique developed at Rochester for a spectrophotometric study of the ozone bands in the region of 2600 angstroms merits the attention of astronomers and meteorologists. If the automatc spectrophotometer of Dr. Brian O'Brien's design could be put into continuous operation at stations strategically located, it would undoubtedly rapidly increase our knowledge not only of the distribution of ozone in latitude but add much to our knowledge of its variation from day to day and ultimately to answer the question of a possible variation with the solar cycle. The spectroscopic method would seem to provide an important supplementary attachment to other methods already in use. The inter-relation of the problem of ozone determination to that of intensity of ultra-violet solar radiation is a problem of fundamental consequence not only in astronomy and meteorology but ultimately in the biological realm as well.

One cannot close a report of the Ottawa meetings without expressing the sincere appreciation of Section D for the hospitality afforded by the Canadian astronomers and particularly by the Director and staff of the Dominion Observatory which was freely open at all times to those attending. Dr. R. Meldrum Stewart, Vice-President and Chairman of the section, presided at all the sessions, the chair also being shared with Dr. R. K. Young of the David Dunlap Observatory on Wednesday morning and with Dr. Brian O'Brien at the Thursday morning session. The attendance at the sessions averaged between thirty and forty.

# Planet Notes for November, 1938

By R. S. ZUG

Note: Greenwich Civil Time is employed, unless otherwise stated. To obtain Eastern Standard Time subtract 5 hours, Central Standard Time, 6 hours; etc. The planetary phenomena are described as they are to be seen from latitude 45° N. The data are taken chiefly from the *American Ephemeris and Nautical Almanac*.

*Sun.* The positions of the sun for November 1 and November 30, respectively, are: $\alpha = 14^h\ 22^m.2$, $\delta = -14°\ 9'.0$; $\alpha = 16^h\ 21^m.2$, $\delta = -21°\ 30'.3$. November opens with the sun in the constellation Libra. On November 23 the sun enters the constellation Scorpius. Values for the equation of time are as follows:

| Date 1938 | Equation of Time (Mean - Apparent) m s | Date 1938 | Equation of Time (Mean - Apparent) m s |
|---|---|---|---|
| Oct. 31 | —16 16 | Nov. 16 | —15 21 |
| Nov. 4 | —16 22 | 20 | —14 33 |
| 8 | —16 15 | 24 | —13 32 |
| 12 | —15 55 | 28 | —12 18 |

*Moon.* Phenomena of the moon will occur as follows:

| | | h | m |
|---|---|---|---|
| Full Moon | Nov. 7 | 22 | 23 |
| Last Quarter | 14 | 16 | 20 |
| New Moon | 22 | 0 | 5 |
| First Quarter | 30 | 3 | 59 |
| Perigee | 11 | 4 | |
| Apogee | 27 | 3 | |

*Eclipses.* A partial eclipse of the sun occurs November 21-22. Observers in the western portions of the United States and Canada will see the moon's disk encroaching on that of the sun, in the late afternoon of November 21, shortly before sunset. Observers in eastern Asia and in Japan will witness the eclipse shortly after sunrise on November 22. The eclipse is visible over a large portion of the North Pacific Ocean.

A total eclipse of the moon will occur November 7-8, visible over most of Europe, Asia, Africa, and the Atlantic, Indian, and Arctic oceans. The beginning is visible in the extreme eastern part of South America and the extreme northeastern part of North America. The ending is visible over North America, except the extreme western and northwestern part, and over South America.

Further particulars concerning these eclipses are published in POPULAR ASTRONOMY, January, 1938, under *Planetary Phenomena in 1938* by Herbert C. Wilson.

*Mercury.* Mercury is an evening star during November, but poorly placed for northern observers. Greatest eastern elongation is reached November 25, the elongation being 21° 51′.

*Venus.* Venus rapidly approaches the sun during the first part of November, and comes into inferior conjunction with the sun November 20. On November 1 the stellar magnitude of the planet is —4.1, and the angular diameter is 52″.7. Only 10% of the disk is seen illuminated on November 1.

*Mars.* Mars is a morning star, rising November 1 about three hours before the sun. On the morning of November 28, observers will find Mars located about

3° north of the bright star Spica, in the constellation Virgo. The stellar magnitude of Mars during November is +1.7.

*Jupiter.* Jupiter is located in the evening sky, crossing the meridian about two hours after sunset November 1. Quadrature with the sun occurs November 16. The planet is moving slowly eastward during November in the constellation Capricornus, and is situated just north of the star δ Capricorni. The stellar magnitude remains close to —2.0 during the month.

*Saturn.* Saturn continues in slow retrograde motion near the southern boundary of the constellation Pisces, and about 2° north of the celestial equator. The stellar magnitude is +0.7.

*Uranus.* Opposition of Uranus and the sun occurs November 8. The positions of the planet for November 1 and December 1, respectively, are: $\alpha = 2^h\,55^m1$, $\delta = +16°\ 18'.1$; $\alpha = 2^h\,50^m4$, $\delta = +15°\ 58'.0$. The planet is situated in the constellation Aries, and is an object of stellar magnitude +6.0.

*Neptune.* Neptune is now observable in the morning sky. The positions of the planet for November 1 and December 1, respectively, are: $\alpha = 11^h\,34^m2$, $\delta = +4°\ 0'.0$; $\alpha = 11^h\,36^m6$, $\delta = +3°\ 46'.0$.

## Asteroid Notes

By HUGH S. RICE

Zeiss binoculars of 50mm aperture enabled the writer to follow the asteroid Pallas as it was progressing on its way in the "circlet of Pisces" as outlined on the chart in the last issue of this magazine. There was no discrepancy great enough to detect on the chart, between the real position and the one drawn. The chart is obviously good for the rest of the season, and the magnitude and place of the planet are such that the object is quite convenient for observation at the present time.

Juno and Vesta however are no longer in good positions for observation. Ceres is still rising so late that it will not be as convenient to observe as in November and December. It is not necessary to give a chart of Ceres now, for the planet in October can be found from the following directions: on the evening of September 30 the position is 1¾° southwest of λ Tauri, and it travels to a point about 1° northeast of ξ Tauri, where it can be found on the evening of November 9. The average magnitude for the period is about 7.5. The apparent path can be marked on the star chart from the above statement, and the asteroid picked up without difficulty.

The famous asteroid Amor, a part of whose orbit is "near" the earth, is at opposition at this time, at the Pisces-Cetus boundary, and, if any astronomer desires to observe it, he must be able to pick up an object of magnitude 20!

There seem to be no other asteroids of magnitude range 8 to 10, after those given in the last issue, until those whose positions are given for November, for us to observe.

Professional observations of Vesta, Juno, Hebe, Pallas, and Thetis were reported to the *Astronomisches Rechen-Institut,* and showed residuals of "zero-zero" —meaning that the observed and computed positions agreed very closely, and that the orbits of these objects are known with a very high degree of accuracy. There are certain others almost in their class. Of course a vast number of asteroids are

continually being observed and reported to the headquarters mentioned, but generally they are of magnitudes ranging from 10 to 14. These observations help the computers to improve the orbits. Most of the observers are in Europe, but there are a few in the United States who are active in asteroid observations.

Some of the minor planets recently named are: Geramtina, Cevenola, Teneriffa, Gotha, Aster, Crocus, Helma, Cimbria, Gefion, Frisia, and Silvretta.

Hayden Planetarium, American Museum of Natural History,
New York, September 18, 1938.

## Occultation Predictions

(Taken from the *American Ephemeris*)

The quantities in the columns *a* and *b* are given for the purpose of making these predictions useful for any place within 200 miles of the point indicated. The procedure is as follows: Subtract the longitude of the point given from the longitude of the place in question; multiply the result in degrees, taking the signs into account, by the quantity under *a* for the star to be observed; similarly, with the latitude, using *b*; apply the sum of the products, with its proper sign, to the Greenwich C.T., and obtain the predicted Greenwich Civil Time for the phenomenon at the place of observation. To obtain Eastern Standard Time it is necessary to subtract five hours; Central Standard Time, six hours, etc.

| Date 1938 | Star | Mag. | IMMERSION Greenwich C.T. (h m) | IMMERSION *a* (m) | IMMERSION *b* (m) | IMMERSION Angle E from N (°) | EMERSION Greenwich C.T. (h m) | EMERSION *a* (m) | EMERSION *b* (m) | EMERSION Angle E from N (°) |
|---|---|---|---|---|---|---|---|---|---|---|
| **Occultations Visible in Longitude +72° 30′, Latitude +42° 30′.** | | | | | | | | | | |
| Nov. 1 | ν Aqr | 4.5 | 0 57.5 | −1.2 | +0.5 | 50 | 2 15.2 | −1.3 | −0.8 | 257 |
| 2 | κ Aqr | 5.3 | 20 49.7 | −1.0 | +1.8 | 74 | 22 4.1 | −1.2 | +1.8 | 237 |
| 2 | 207 B.Aqr | 6.4 | 23 40.8 | .. | .. | 4 | 0 28.5 | .. | .. | 297 |
| 10 | 333 B.Tau | 6.5 | 1 49.7 | −0.3 | +1.6 | 75 | 2 51.3 | −0.8 | +1.1 | 270 |
| 10 | 107 Tau | 6.6 | 3 19.0 | −1.0 | +1.4 | 85 | 4 29.6 | −1.4 | +1.1 | 263 |
| 10 | 351 B.Tau | 6.2 | 9 17.4 | .. | .. | 25 | 9 40.9 | .. | .. | 346 |
| 10 | 353 B.Tau | 6.4 | 9 49.0 | −1.0 | −1.3 | 100 | 10 55.4 | −0.7 | −1.4 | 273 |
| 11 | 71 Ori | 5.2 | 5 15.4 | −1.6 | −0.1 | 118 | 6 24.4 | −1.6 | +1.5 | 248 |
| 13 | 30 B.Cnc | 6.1 | 3 34.6 | +0.4 | +3.0 | 47 | 4 9.2 | −0.7 | −1.0 | 332 |
| 15 | 14 Sex | 6.3 | 6 7.7 | −0.4 | 0.0 | 132 | 7 5.5 | −0.7 | +1.4 | 267 |
| **Occultations Visible in Longitude +91° 0′, Latitude +40° 0′.** | | | | | | | | | | |
| Nov. 1 | ν Aqr | 4.5 | 0 29.7 | −1.3 | +1.9 | 28 | 1 43.8 | −2.6 | −1.0 | 278 |
| 5 | 51 Psc | 5.7 | 9 5.5 | −0.4 | +1.8 | 17 | 9 38.6 | +0.2 | −3.2 | 308 |
| 10 | 333 B.Tau | 6.5 | 1 45.4 | +0.3 | +1.7 | 63 | 2 37.4 | −0.4 | +0.8 | 282 |
| 10 | 107 Tau | 6.6 | 3 4.0 | −0.3 | +1.6 | 73 | 4 5.5 | −0.8 | +1.0 | 272 |
| 10 | 351 B.Tau | 6.2 | 8 31.8 | −2.1 | +1.5 | 55 | 9 34.5 | −1.5 | −2.5 | 310 |
| 10 | 353 B.Tau | 6.4 | 9 27.9 | −1.5 | −1.8 | 122 | 10 35.9 | −1.7 | −0.1 | 248 |
| 11 | 71 Ori | 5.2 | 4 51.5 | −1.0 | +0.5 | 112 | 5 54.3 | −1.0 | +1.8 | 247 |
| **Occultations Visible in Longitude +120° 0′, Latitude +36° 0′.** | | | | | | | | | | |
| Nov. 5 | 51 Psc | 5.7 | 8 40.2 | −1.0 | +1.5 | 31 | 9 37.5 | −1.0 | −2.0 | 284 |
| 10 | 107 Tau | 6.6 | 3 2.2 | +0.6 | +1.7 | 53 | 3 46.9 | −0.2 | +0.5 | 293 |
| 10 | 351 B.Tau | 6.2 | 7 34.0 | −1.3 | +2.2 | 59 | 8 43.3 | −2.1 | −0.5 | 292 |
| 10 | 353 B.Tau | 6.4 | 8 38.3 | −2.4 | −2.5 | 140 | 9 29.0 | −1.9 | +3.5 | 216 |
| 11 | 71 Ori | 5.2 | 4 36.3 | +0.1 | +0.9 | 96 | 5 30.9 | −0.2 | +1.2 | 261 |
| 14 | ω Leo | 5.5 | 14 14.1 | −2.9 | +0.9 | 71 | 15 8.9 | −0.6 | −3.4 | 345 |
| 18 | χ Vir | 4.9 | 12 46.3 | +0.2 | −2.5 | 172 | 13 23.4 | −1.7 | +3.0 | 239 |
| 26 | ρ Sgr | 4.0 | 2 55.2 | −0.4 | +0.2 | 48 | 3 57.7 | −0.6 | −1.4 | 274 |

## Comet Notes

By G. VAN BIESBROECK

The unusual absence of observable comets continues. PERIODIC COMET 1927 VI (GALE), which was recovered last spring and remained too far south during the summer months, now comes north again, but it is doubtful if it can yet be recorded even in large instruments; its course can be seen by the following prediction from E. Cunningham's orbit given by *Harvard Announcement Card* 452:

| 1938 | α h m | δ ° ′ | M |
|---|---|---|---|
| Oct. 5 | 23 21 | —28 14 | 15 |
| 13 | 23 20 | 26 4 | 15 |
| 21 | 23 21 | 23 56 | 16 |
| 29 | 23 23 | 21 51 | 16 |
| Nov. 6 | 23 27 | —19 50 | 17 |

A very uncertain prediction after an interval of 20 years would place PERIODIC COMET 1918 III (SCHORR) in the constellation of Cetus in October. It is very faint and the position indicated may be in error by many degrees.

The only other expected comet is PERIODIC COMET KOPFF which comes nearest to the sun next March. It is, however, too unfavorably situated for northern observers until the early months of next year.

Williams Bay, Wisconsin, September 21, 1938.

# METEORS AND METEORITES

## Meteor Notes from the American Meteor Society

By CHARLES P. OLIVIER, President

The most interesting very recent publication on meteors to be received is the report of Commission No. 22 of the International Astronomical Union, which is the Meteor Commission, now under the able presidency of M. Felix de Roy of Antwerp. This deals with the progress of meteoric astronomy during the past three years and covers 10 closely printed pages. There is also an appendix of seven pages dealing with the light of the night sky. My remarks are confined to the report proper, and I sincerely wish that a copy could be in the hands of every meteor observer so that he could see the immense amount of work now being carried out in this field, and know where and by whom it is being done. There are now 16 countries (17 until Austria was so honorably "absorbed" by Germany) which have societies or central bureaus dealing with meteors. As some countries have more than one, there are actually 21 societies, etc., the United States being credited with three, the American Meteor Society, Midwest Meteor Association, and Society for Research on Meteorites. Individuals in other countries, not among the 16 listed, undoubtedly do some work on meteors but have as yet no known organizations.

The report proper has 13 subjects treated, some observational, some theoretical. Meteor trains are mentioned briefly only in Section 2. This is not due to lack of appreciation as to their importance but because no paper has appeared in the past three years dealing with their phenomena in the general sense. Section 3, on telescopic meteors, indicates some progress and coöperation. I should like again

to call to the attention of persons with telescopes of from three to six inches aperture, and with low powers and hence wide fields, the importance of systematic observations for telescopic meteors. Others who have powerful binoculars could do similar work. For many years the A.M.S. has urged variable star observers to report all telescopic meteors, casually seen. This should be kept up. But the time has now come when we need persons to observe telescopic meteors *only*, watching one field for such period as their eyes can stand. The work, frankly, is a most trying one on the eyesight. Section 5 deals with the photography of meteors and the use of the rotating sector by which a meteor's velocity may be computed, if a duplicate observation is available. Obviously short-focus lenses of wide fields are recommended, but still there seem to be no plates fast enough to insure the photographing of the average second magnitude meteor. Experiments, however, are being made in many places, and numerous meteors have been photographed during the past three years. The determination of radiants on photographic plates, as developed in Belgium by S. Arend and E. Vanderkerkhove for the fine Draconid shower of October, 1933, has shown what superb results may be obtained. However, for the determination of heights by photography from two stations, there is never any certainty that the beginning point and the end point as secured on each plate correspond to exactly the same *absolute* point in space, unless indeed there is some great burst which can be definitely identified on each plate. This trouble fortunately has no effect upon the accurate determination of the radiants from two such simultaneous photographs. Section 7, on fireballs, suggests a sequel to the von Niessl-Hoffmeister Catalogue. In the final suggestions, of which there are 18, the eighth is that papers on the true heights of meteors should contain the observations themselves. While ideally excellent, such a procedure is often hopelessly impracticable, due both to the necessity for interpreting much of the data submitted and, most of all, to the immense cost of publication. When over a hundred reports come in, mostly from untrained people, there is nothing to do but trust to the good judgment of the man who works them up. If he makes mistakes in judgment, it is at least probable that another computer, using the same data, would make equally bad if not worse ones, for such heights rarely permit of a definitive solution. We have to try to derive the most probable one.

Among our observers who have sent in good reports in June or July or both are W. R. Morris, Gordon Green, J. L. Sullens, W. R. Stone, and Gerald Pirsig. Three of these are new members who are making a good start. The Delta Aquarid meteors, to date, have been reported as follows: 1938 July 27/28, at Blue Earth, Minnesota, by G. Persig, 25 meteors in 140 minutes; $F = 0.9$. Only a small fraction were Aquarids. July 26/27 at Santa Barbara, California, by W. R. Stone, 15 meteors in 240 minutes, $F = 1.0$; July 27/28, 10 meteors in 210 minutes, $F = 0.7$. July 30/31, at Constantine, Michigan, by W. R. Morris, 20 meteors in 120 minutes, $F = 0.5$. Bad weather and heavy rains prevented observations over much of the eastern seaboard.

Observations are greatly desired here upon all of the following fireballs. Some of these indicate that long-enduring trains are still unreported in the vast majority of cases, despite the persistent efforts made to arouse the consciousness of persons interested in science as to their importance. (1) 1937 June 21, 7:50 P.M., C.S.T., seen from near Denton, Texas, fireball leaving train visible 15 to 20 minutes. The report is in the July, 1938, Texas Observers Bulletin. Observations from others would be most valuable. (2) 1938 July 5, 8:45 P.M., C.S.T., seen from near Nashville, Tennessee, fine object. (3) 1938 July 29/30, 12:20 A.M., seen from near Cheney, Washington, fireball leaving 5-minute train. (4) 1938 August 3, 11:45

P.M., M.S.T., from near Westminster, Colorado, fireball with 30-second train. (5) 1938 July 6, 8:17 P.M., M.S.T., seen near Ysidro, New Mexico, brilliant fireball. (6) Several of our A.M.S. members are now collecting data for me on the New York fireball of 1938 July 26. If anyone has an unreported observation, please let me have it promptly.

Flower Observatory, Upper Darby, Pennsylvania, 1938 August 10.

# Contributions of the Society for Research on Meteorites

*Edited by* FREDERICK C. LEONARD,
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*President of the Society:* H. H. NININGER, Colorado Museum of Natural History and American Meteorite Laboratory, Denver

*Secretary of the Society:* ROBERT W. WEBB, Department of Geology, University of California at Los Angeles

## The History of the Name Widmanstätten: A Few Previously Unpublished Facts

*By* F. A. PANETH,
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*Abstract.*—Extensive historical investigations have shown that the discoverer of the etching figures characteristic of many irony meteorites called himself "Widmanstätten"; accordingly, there is no reason to deviate from this spelling, since the man himself employed it. Indeed, it would be an historical falsification to use any other form, even though the *family* of Widmanstätten does use *today* the name "Beckh-Widmanstetter."

The name of Widmanstätten has not only, for more than a hundred years, very frequently been used in meteoritics, in the term "Widmanstätten figures," but more recently has entered the wider field of general metallurgy, since the characteristic "Widmanstätten structure" has been found in alloys of very different composition.[1] The Editor of these CONTRIBUTIONS, Dr. F. C. Leonard, has drawn attention to the fact that in 1933 the spelling "Widmanstätten" was denounced as incorrect and "Widmanstetter" advocated in its place,[2] but that the arguments used have been challenged.[3] The later development of this dispute has not been abstracted in this journal, but is easily accessible.[4] When Dr. Leonard visited the author a few weeks ago at the Imperial College of Science and Technology in London, he was interested to see the correspondence, with Austrian friends, on which the author's conclusions were based and of which, for the sake of brevity, in *Nature*, only the main points have been communicated. In pursuance of Dr. Leonard's suggestion, a few of the hitherto unpublished facts which were established in the course of these historical studies are here put on record.

It has been said that "Widmanstätten" is a misspelling of the "correct Widmanstetter," a mistake made by the scientist's contemporaries. But documents show that both forms (and several others) were officially in use in the sixteenth, seventeenth, and eighteenth centuries, and that the discoverer of the etching figures himself preferred the spelling with "n" at the end of his name. This fact is con-

vincingly shown in documents preserved in Graz (Styria) about the ownership of the house No. 5 on the Postplatz (Post Office Square), which for this special purpose have been examined by Dr. P. Puntschart, Professor of History at Graz University. We give here an abstract of his list:

1596: Georg Widmanstetter, printer.
1663: Franz Widtmannstetter.
1674: Widmanstätterische Erben and Printing Office.
1708: Printing Office of Anthon Böckh.
1728: Ferdinand Böckh or Widmanstötterische Erben.
1746-53: Otto Johann Böckh.
1753-78: Franz Josef Beck.
1778-1848: Aloys Beck von Widmanstetten.

From these documents we learn: (1) that the spelling, not only of "Widmanstätten," but also of the other name, "Beckh," varied from one generation to the next; (2) that the name of the last-mentioned owner of the house, the well-known scientist, is here, in an official document, written with the final "n," not "r."

The somewhat bewildering changes in the names became clearer by the information which was kindly given by a member of the family, Dr. Phil. et Med. Hans Albrecht Beckh-Widmanstetter, in Raabs an der Thaya (Austria). According to him, the original owners of the printing office called themselves mostly "Widmanstetter," but after the male line of the family had died out and was followed in the ownership of the printing office and house by the family Beckh, these styled themselves usually "Widmanstättensche Erben" ("Heirs of the Widmanstätten"). Later, "Widmanstätten" was added to their own family name, "Beckh." "Beckh," "Böckh," or "Beck," is, of course, nothing but the South-German form of "Bäcker" ("Baker"); and just because he disliked this name with its too obvious implication of ancestral occupation, Aloys Beck von Widmanstätten dropped his original family name entirely and used only the "Widmanstätten." Several decades ago the then-living members of the family decided to adopt the form "Beckh von Widmanstetter"; this spelling is now, according to modern custom, uniformly and strictly observed by all, "Beckh" again being the proper name, "Widmanstetter" a titular distinction. (Accordingly, in the telephone directories, members of the family are to be looked up under "B," and not under "W"!)

This, and similar, information led to the conclusions reached in *Nature*, **140**, 809, 1937: "The issue now simply is whether we want to adopt the form of the name used by other members of the family, or the one chosen by the man himself. Those who prefer the former alternative should speak of 'Beckh-Widmanstetter figures,' or simply 'Beckh figures,' for 'Beckh' is the real family name. The discoverer of the etching figures, however, had dropped the 'Beckh' entirely, called himself 'Widmanstätten,' and was officially and privately known under this name." Or, to quote from a letter by Professor Stephan Meyer (Vienna), in which he summarizes the results of his extensive researches: "The discoverer of the etching figures called himself 'Widmanstätten,' and one cannot deny him the right to pick out of the various orthographies the one which he liked best. There is no reason to deviate from the spelling 'Widmanstätten,' since the author himself wrote it; so it would be an historical falsification to change it, although today the family uses the name 'Beckh-Widmanstetter.'"

References

[1] See C. H. Desch, "The Chemistry of Solids" (Cornell University Press, New

York, 1934), where a whole chapter is devoted to the discussion of the Widmanstätten structure.

[2] L. J. Spencer, *Min. Mag.*, **23**, 331, 1933; F. C. Leonard, *C.S.R.M., P.A.*, **45**, 49, 1937, and **1**, Fasc. 3, 5, 1938.

[3] F. A. Paneth, *Nature*, **140**, 504, 1937; F. C. Leonard, *C.S.R.M., P.A.*, **45**, 508, 1937, and **1**, Fasc. 3, 57, 1938.

[4] L. J. Spencer, *Nature*, **140**, 589, 1937; F. A. Paneth, *Nature*, **140**, 809, 1937.

1938 August 15

# Notes from Amateurs

### The New Haven Amateur Astronomical Society

The last meeting of the season of the New Haven Amateur Astronomical Society was held on June 11 with an attendance of 28 members.

The society has had a number of prominent speakers in the astronomical field address it and has also been quite successful in having among its own members a number of amateurs who have presented various subjects that have been a credit to their knowledge and understanding and have proven very instructive and beneficial to the group.

In keeping with that policy Miss May gave a five minute talk on Venus and reviewed and brought out many interesting facts and figures concerning the planet which were appreciated by her listeners.

Reports were made by Mr. Neale, chairman of the Telescope Group, concerning two demonstrations made at the last meeting of this group, showing a novel way to make a pitch lap (for polishing lenses) by means of a rubber mat, the individual squares or facets being poured singly after which the mat was removed and the polished lens cold pressed against the pitch, the second demonstration was made by making a convex plaster cast form the fine ground lens, and then cutting in the cross grooves from which a concave plaster cast was made with the cross grooves raised, and this form was then pressed into the newly poured pitch lap and both the grooves and approximate circular curve was transferred to the lap.

Messrs. Anyzeski, Neale, and Dr. Rademacher each gave a detailed account of the recent meeting of the A.A.V.S.O. held in Providence, R. I., on May 27. Their account was very interesting and the six members of our group who attended this session were very enthusiastic over the meeting.

The following summer activities were announced.

June 27. Observing party for the Gamma Draconids meteor shower.
July 16. Picnic for members and families at Mt. Carmel, with telescopes of various sizes and kinds set up for observing in the evening.
July 28. Observing party for the Delta Aquarids shower.
August 6. Trip to Springfield, Vt., to attend the Amateur Telescope Makers' Annual Meeting. (Ten of our members attended last year.)

There are a number of tentative plans still in the hands of the committee.
October 17. First meeting of fall.

Mr. Wm. Glowacki (a member of our society), as speaker of the evening, addressed the group on "Surface Markings on Mars" and said in part that the first drawings of Mars were made by Huygens in 1659. He sketched various landmarks in Martian discovery illustrating salient points by slides loaned by the Van Vleck Observatory. Three epochs of discovery were noted, those associated

with the names of Galileo, Herschel, and Schiaparelli. The last mentioned was the first to discover the famous canals and thereby precipitated an argumentative war that persists even to this day.

Mr. Glowacki emphasized that the faint planetary detail at the limits of vision and perspective cannot be studied photographically with much profit. The canals of Mars can be seen only with the eye through a good telescope, though not necessarily a large telescope, and then only at certain few places on the Earth with favorable seeing conditions. Observers must be skilled and well experienced to see these faint markings.

Several slides illustrating Simon Newcomb's work on the subjective side of this phenomenon were of particular interest. He made it apparent from many slides shown that an eye conditioned by a preconceived notion could easily integrate many faint impressions to give the sharp lines that typify the canals as drawn by Lowell.

In the speaker's final summary he showed that Mars, though smaller, differs mainly from the Earth in being colder and dryer. Earthmen could possibly live on Mars though with difficulty, but of all the planets in our system it is the best furnished for life as we know it and will always hold our interest. In 1940 Mars will be 36 million miles distant and well situated for observation.

F. R. BURNHAM.

### The New Haven Amateur Astronomical Society

After an eventful summer in which the N.H.A.A.S. participated in a number of interesting gatherings among them a picnic in July with observing in the evening, a delegation of eight attending the Telescope Maker's Annual meeting in Boston on July 23, fifteen members attended the convention at Stellafane on August 6, and an observing party with the 9-inch refractor in the Yale Observatory on August 30.

The first meeting of the season was held on September 17 with twenty-nine present and the subject was "Telescope Making Explained and Demonstrated." Some of the major operations were demonstrated such as mirror grinding and polishing. Foucault testing and mirror silvering were explained by black board sketches and diagrams, while one experienced in these operations was performing the respective operations. By this method all present obtained a very clear idea of a few of the problems (or pleasures) of telescope making. Several large and small mirrors in process as well as other parts were on exhibition as was also a complete 4-inch reflector with clock drive, and a 6-inch reflector with portable mount, all made by members.

Mr. Becroft had his Mirror Grinding Machine in operation in contrast to hand grinding and it was the center of considerable interest.

F. R. BURNHAM, *Secretary.*

### The Astronomical Society of Nevada

On Saturday evening, July 29, the Astronomical Society of Nevada held its fourth annual summer telescope meeting. About fifty people, members of the society and their families, attended a sunset picnic on the new Geiger Grade highway which leads through the Virginia mountains to the historic Comstock Lode.

After sunset, telescopes were unlimbered and views of Mercury and Venus were obtained before they sank out of sight behind the ridges of the Sierra Nevada to the west. When darkness came on, the interesting regions of Sagittarius and Scorpio were explored under the nearly perfect seeing conditions of the clear

mountain air. Jupiter also came in for its share of attention. Several telescopes were available among which were a 5½-inch Alvin Clark refractor and an excellent 8-inch reflector of amateur make.

The Society has held well-attended monthly meetings throughout the past year. Outstanding among these was a meeting in the American Legion hall in Carson City. At this meeting preliminary plans were proposed for the building or purchase by the Society of a 24-inch reflector to be housed on or near the campus of the University of Nevada. After the meeting, many members took advantage of the opportunity to use the 10-inch reflector of the new Jim A. Grant Observatory. Mrs. Marion Grant Bowen, owner of the observatory, received from the Society a small sidereal clock as a memento of the occasion.

Another program which aroused considerable interest dealt with the aurora borealis. The discussions on the program were: "The Aurora in its Home," by Professor J. C. Church; "The Aurora as I Saw it in Greenland," by Mr. Fred Herz; and, "How Scientists Attempt to Explain the Aurora," by Mr. John L. Carlson.

The members of the executive committee of the Astronomical Society of Nevada are: G. B. Blair, President; Mrs. L. W. Hartman, Vice President; John L. Carlson, 736 West St., Reno, Nevada, Secretary-Treasurer; F. L. Bixby, Chairman, Program Committee; Everett W. Harris, Member-at-Large.

G. B. Blair.

## General Notes

**Dr. Ernest William Brown,** Josiah Willard Gibbs professor of mathematics emeritus at Yale University, died on July 22 at the age of seventy-one. An account of his many contributions to the astronomical science will appear in a later issue of this magazine.

**Russian Astronomers.**—The Polish journal *Acta Astronomica,* in its July issue, states that the following members of the staff of the Pulkovo Observatory have been imprisoned: I. A. Balanovsky, N. I. Dneprovsky, B. P. Gerasimovic (director), P. I. Iaschnoff, B. W. Noumeroff (director of the Astronomical Institute at Leningrad, who is believed to have been shot), N. W. Zimmerman. The Editor of *Acta Astronomica* states that it would give him great pleasure to be able to refute this statement, a sentiment which we are sure scientific workers everywhere will echo (*Nature,* August 27, 1938).

### International Union of Geodesy and Geophysics

Information has been received that the President of the United States has invited the International Union of Geodesy and Geophysics to hold its seventh general assembly in the United States in 1939. The invitations have been extended on behalf of the President by the Department of State through its diplomatic missions to the governments to which these missions are accredited, and invite the participating countries to be represented by delegates on this occasion.

It is planned to hold this seventh triennial assembly of the Union in Washington, September 4-15, 1939, according to a statement made by Dr. John A. Fleming, Director of the Carnegie Institution's Department of Terrestrial Magnetism, who is General Secretary of the American Geophysical Union. The American

Geophysical Union is the American Section of the International Union of Geodesy and Geophysics, and its Executive Committee is the Committee on Geophysics of the National Research Council. The Council is collaborating with the American Geophysical Union as host to the assembly. The last general assembly of the International Union was held at Edinburgh, Scotland, in September, 1936.

The thirty-five nations at present adhering to the International Union are: Argentina, Belgium, Brazil, Bulgaria, Canada, Colombia, Chile, Czechoslovakia, Denmark, Egypt, Finland, France, Germany, Great Britain, Greece, Holland, Hungary, Indo-China, Italy, Japan, Morocco, Mexico, New Zealand, Norway, Peru, Poland, Portugal, Rumania, Siam, Spain, Sweden, Switzerland, Union of Soviet Socialist Republics, United States, and Yugoslavia.

Washington, D. C., September 12, 1938.

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**Jupiter X and Jupiter XI.**—This designation indicating a tenth and an eleventh satellite of Jupiter will require a modification of existing textbooks in astronomy and a revision of thought on the part of astronomers who, since 1914, have considered Jupiter as having only nine satellites. The announcement of the discovery of these two new satellites was made by *Harvard Announcement Card*, No. 455, under date of August 31, 1838, as follows:

"Two new satellites of Jupiter were discovered at the Mount Wilson Observatory of the Carnegie Institution of Washington by Seth B. Nicholson on photographs made with the 100-inch telesccope. Both are about magnitude 19. Their approximate positions were

| X — Jupiter | | | XI — Jupiter | | |
|---|---|---|---|---|---|
| 1938 | $\alpha$ | $\delta$ | 1938 | $\alpha$ | $\delta$ |
| | m | | | m | |
| July 6 | —0.6 | +29′ | July 30 | +6.4 | +23′ |
| July 29 | —2.9 | +22 | Aug. 1 | +6.4 | +23 |
| Aug. 25 | —4.6 | + 6 | Aug. 25 | +6.1 | +11 |

Later, the right ascension and declination for these new objects were determined as follows:

Jupiter X, Aug. 1.3194 U.T., $22^h\ 06^m\ 05^s.78$; —12° 18′ 46″.3
Jupiter XI, Aug. 1.4674 U.T., 22 15 27.29; —12 16 14.1

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### Notes from the Yerkes and McDonald Observatories

Dr. Thornton L. Page, of the University of Oxford, England, has been appointed instructor of astrophysics at the University of Chicago. Dr. Page will give several courses on the campus of the University during the autumn and winter quarters. The remainder of his time will be devoted to research at the two observatories. Dr. Page received his undergraduate training at Yale University. His graduate work was done at Oxford. Dr. Philip C. Keenan will be at the Yerkes Observatory during the autumn and winter quarters, devoting his time mostly to solar research. During the spring quarter he will teach on the campus of the University. Dr. John Titus, formerly of Columbia University, has been appointed volunteer research assistant. He will be engaged in proper-motion and parallax work. Mr. Carl F. Rust and Mr. John O'Keefe, the latter of Harvard University, have been appointed to University fellowships at the Yerkes Observatory. Mr. Rust is engaged in radiometric and spectroscopic observations of very cool stars.

Professor Frank E. Ross left for Pasadena, California, on September 17, after six months of work at the Yerkes Observatory. He completed his investigation

of the limiting magnitudes of stars which can be photographed with different types of reflectors, and continued the work of discovery of proper-motion stars.

Dr. Paul Rudnick and Mrs. Jessie Rudnick will be at the Yerkes Observatory for six months, beginning October 3. Mr. Walter Linke has been appointed assistant at the McDonald Observatory to replace Dr. Rudnick. Mr. E. L. McCarthy has been on a leave of absence at Cleveland, Ohio, since May 23, 1938. He has assisted at the Warner and Swasey Company in the optical tests of the 82-inch mirror. Professor G. P. Kuiper and Miss Mary R. Calvert attended the meeting of the I.A.U. at Stockholm. O.S.

### Some Astronomical Analogies

In pointing out the constellations on various occasions several simple analogies or illustrations have occurred to me which seemed to register pretty well; and because they may prove helpful to others, a few of these are given below:

*The Constellations Compared to States.* I ask the audience to imagine the heavens as similar to a map of the world divided into hemispheres and into territories or countries. The latter in turn are to be subdivided into the constellations which correspond to the various states and provinces. And just as the borders of states were at first somewhat arbitrarily or accidentally determined, though now and then more or less natural features are made use of, so with the constellations. The bright stars correspond to the big cities in each state; some star states have quite a few, others only one or two, just as with the states. The very brightest stars like Sirius, Canopus, Vega, and Arcturus correspond to the largest cities like New York, London, Paris, Berlin. The fainter stars correspond to the lesser cities till eventually we come to the smaller towns which are not on the smaller scale maps at all but require special regional maps or star charts. It is most important to know all the brighter stars just as to know all the larger cities, but this is appropriately to be done by knowing something of the state or constellation in which they are found.

*The Seasonal Constellations.* I ask the audience to think of the sun as represented by an island in a lake. The earth is to be thought of as a boat going around the island once a year and seeing in turn various parts of *the shoreline of the stars.* The sun island has large trees corresponding to the sun's rays which prevent our seeing any of the shoreline across the island just as the bright rays prevent our seeing the winter constellations in daylight in summer. If we further think of the earth boat as an ultra-modern pleasure-spin boat which rotates as it proceeds we further illustrate the diurnal rising and setting of the nightly constellations—those away from the island.

*The Various Nebulae.* I ask the audience to think of a cloud of vapor or smoke or gas. The word nebulous means hazy or misty like such a cloud. That appearance is shared by quite a variety of astronomical phenomena which upon further resolution are found to be rather different. Through our various astronomical instruments we have greatly clarified many of our hazy or nebulous notions about the various celestial nebulosities. Some of the nebulous patches in the sky turn out to be really nebulous in nature, like that of the Orion nebula in the great star state of Orion and those surrounding the bright stars of the Pleiades constellation. (These are pointed out.) But the Milky Way clouds, the cluster in Hercules and others like it, and the Andromeda Nebula and other extra-galactic nebulae, these all turn out to be not small gaseous particles relatively near, but actual systems of stars like our sun at tremendous distances. In a sense, however, the stars are *gigantic particles of giant gases,* so perhaps our original word is not

misleading after all. Giant gases at tremendous distances, or dwarf gases nearer by, have about the same appearance; and with the microscope the particles of an ordinary gas become indeed as stars, and through the instruments of mathematical physics we see those single and multiple stars, the atoms and molecules, each with their planets in their orbits accompanied sometimes by their satellites or moons, and who can say that some of these minute worlds may not be peopled by pigmy races of Lilliputians?

*Are Stars Pointed?* If we take a sphere of soft material and throw it on the ground it *splashes* and takes on a *burred* or *pointed* appearance. In a roughly similar way what would be the tiny rounded point of light from a star is *spattered* in various directions when it strikes the irregularities and turbulences of the earth's atmospheric blanket giving the pointed appearance we see.

In speaking to groups of very young persons I have found it helpful to have various members act out certain planetary motions and such constellations as the big dipper, northern cross, or Cassiopeia. A person moving about another whom he always faces illustrates the moon's always facing the same toward the earth yet still turning on its axis. A giant and dwarf star in a constellation can be illustrated by using larger and smaller individuals to take these parts, and for a colored double like Albireo two girls with reddish and bluish dresses bring out the idea. Common proper motions of the big dipper stars can be illustrated by the group acting out this constellation taking several paces in the same direction. Other possibilities of this general procedure will readily suggest themselves.

Yerkes Observatory, July, 1938. CHARLES HETZLER.

### An Aurora Observed in Ohio

An unusually brilliant auroral display for this locality and season was first noted by the writer while driving through the outskirts of Columbus, Ohio, about 11:00 P.M. on the night of May 24-25. After arriving at this observatory, 27 miles east of Columbus, it was possible to give the aurora more careful examination. At 12:15 its general form was similar to the 11:00 P.M. appearance. A band eight to ten degrees wide arched over more than one-third of the horizon, its axis at 12:40 being very closely the ten and twenty-two hour circles. If the horizon had not been restricted to altitudes of six and nine degrees in the east and west, respectively, it is probable that it could have been traced over more than the 130° of azimuth that it was seen to cover. When most conspicuous it was markedly brighter at corresponding altitudes than the Cygnus and Scutum Cloud regions of the Milky Way. At 12:20 the central portion of the band had faded out, the remaining segments near the horizon exhibiting dark rifts and a cloudlike irregular structure. Within twenty minutes the center brightened up, and the whole took on a more regular appearance. During the drive east from Columbus at least one narrow ray was seen stretching upward from the northern horizon, and crossing the main arc like the spoke of a ship's steering wheel. By 1:20 the display was over. No reports have been received here that it was visible much before 11:00 P.M. Due either to the late hour, or unfamiliarity with the appearance of the aurora, few students on this campus seem to have noticed it, although it was one of the finest of recent displays. FREEMAN D. MILLER, *Director.*

Swasey Observatory, Denison University, Granville, Ohio.

### Aurora Widely Observed

The night of September 27 furnished unusually brilliant aurora phenomena over a wide area. Reports have been received from Mr. Charles H. Brockmeyer,

Jr., Fredonia, Kentucky, Mr. Frederick K. Vreeland, Gardner, Colorado, and Professor Floyd C. Fairbanks, Rochester, New York. At the same time practically the entire sky here (Northfield, Minnesota) was illuminated, with strong condensation at the zenith. We regret that space is not available to publish more of the details given in the communications mentioned above.

## Book Reviews

**Elements d'Astronomie et de Géodésie,** by J. F. Cox. (Maison Desser, 21 rue Sainte Véronique, Liege, Belgium.)

This is a large-sized mimeographed volume of 224 pages, arrangeú in ten chapters. Evidently it is intended as a textbook because the author has included a set of "exercises" following each chapter. It is elementary in character and the explanations presented are frequently amplifid by appropriate diagrams. It should have a wide use in schools in which French is the standard language.

**Lumière Nouvelle,** by L. A. Jacquin. (Joannes Desvigne et Cie., Lyon, France.)

The above is the title of a small brochure of fifty pages. There are four chapters dealing, respectively, with: Radiation, Origin of the Universe, Theory of Gravitation, and Theory of Inertia. Apparently, the pamphlet presents the reflections of a retired gentleman who has pondered these fundamental physical entities for a number of years. Some of the thoughts are in keeping with present-day beliefs and some are slightly at variance with them. The same author has elaborated his discussions in a larger volume entitled "L'Equilibre Universal." The central theme in this one seems to be sociological rather than astronomical.

They are, as the titles show, in French.

**Astronomy for the Millions,** by Professor van den Bergh. (E. P. Dutton & Co., Inc., 300 Fourth Ave., N.Y.C. $3.50.)

The book bearing the above title was issued about a year ago. It is a translation by Joan C. H. Marshall and Th. de Vrijer from the Dutch edition. The style and manner of exposition are quite unique, so it seems that the translators have succeeded in retaining the excellent quality of the original. At times the imagination is given considerable freedom, as in the description of a holiday on the moon or a rocket journey to Mars, but the experiences depicted are in keeping with generally accepted theories, and the fancy of the reader stimulates his intellect in the endeavor to grasp the ideas presented.

One is tempted to include in the review some of the especially succinct paragraphs found throughout the book. One, however, in attempting to make a selection is baffled by the numerous possibilities. The entire range of astronomical material, from the earth and its companion planets, the sun, the Galaxy, to the exterior and very remote stellar systems, is comprehensively treated. Although the author writes with depth and authority, at no time does he become abstruse and technical, so the attention of the reader is held and stimulated, and a fine climax is reached in the concluding chapter which is entitled "Past and Future."

The volume contains 355 pages of reading matter and twenty pages of topical index. It cannot be read as rapidly as a book of fiction, but the reader will feel

well repaid for whatever time and effort he may devote to it. There is no lack of similar books but this stands out prominently in its class. The title may seem ambitious or even presumptuous to some, but an intelligent reading will lead to the conclusion that it is amply justified. Millions of people might well read it with pleasure and profit.

We shall close this brief and inadequate review of this unusual volume by quoting the final sentence in it, as characteristic of the outlook and spirit of the author: "But in our hearts we can cherish the reassuring certainty that the Universal cannot but be good and beautiful."

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**Astronomy,** by Robert H. Baker. (D. Van Nostrand Company, Inc., 250 Fourth Avenue, New York. $3.75.)

This is the third edition and the eighth printing of this well-known text. An extended review of the first edition appeared in volume 38 (1930), page 515, of this periodical. The reason for a new edition is stated in the preface, as follows: "Advances in the various branches of astronomy since the appearance of the second edition have produced new data and new viewpoints. These and further experience in the use of 'Astronomy' in the class-room prompted a thorough revision intended to bring the book again up to the times and to otherwise increase its value for text and reference purposes."

A new feature in this edition is a list of review questions at the end of each chapter which furnishes the student with a check upon his comprehension of the material presented in the chapter.

An excellent quality of paper is used which shows the numerous photographs to the best advantage. There are more than 500 pages of text, supplemented with a page of Astronomical Constants, and an extended index of names and of subjects.

It is out of the question to attempt to comment upon all the commendable features of this book. They are too numerous. But it is worthy of the highest recommendation for "text and reference purposes" for which it is intended.

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**What New Wonders,** by A. M. Low. (Herbert Joseph, Ltd., 4 Adam Street, Adelphi, London. 5 shillings.)

This volume, of 107 pages, has as its sub-title, "The Story of the Giant Pasadena Telescope." To remove possible ambiguity, it should be said immediately that the book pertains to the 200-inch mirror now being ground in Pasadena and later to be set up on Mt. Palomar, California, and not to the 100-inch telescope on Mt. Wilson, near Pasadena, which has attracted wide-spread interest since its installation nearly a score of years ago.

The volume before us is one of many attempts to give information to the general reading public concerning this enormously expensive and highly scientific project. It is, perhaps, not to be expected that such writings be technically precise in all details. Their purpose is inspirational rather than scientific. It is necessary to view this volume in this light in order to evaluate it adequately and not too critically. For example, the jacket cover speaks of "grinding the enormous *lense*." The final word is wrong in two respects, spelling and connotation. The responsibility here may be the publisher's rather than the author's. However, it does not inspire confidence on the part of the reader who notices such flaws. Nevertheless, overlooking these minor defects, the average reader will get from the

volume the impression it is intended to convey, namely, that, although stupendous obstacles and difficulties arise in the prosecution of this unique undertaking, the genius and perseverence of man are able to cope with them and to bring the experiment to a successful conclusion.

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**Astronomical Fundamentals for Everyone,** by Rolf Müller. (Johann Ambrosius Barth, Leipzig. 8.50 marks.)

The above is a free translation of the title of a book recently issued in German. It presents in alphabetical order the definitions of words and the explanation of terms which the reader of astronomical literature encounters. It might, therefore, be characterized as an astronomical dictionary or encyclopedia. Sometimes a few lines suffice for the definition but, where needed, a page or more is devoted to a complete elucidation of the term. The verbal explanations are frequently supplemented by well-chosen illustrations. It constitutes a useful and convenient reference work for the beginner in astronomy who reads the German language readily.

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**Astronomy,** by W. M. Smart. (Oxford University Press, 114 Fifth Avenue, New York. $1.50.)

The book before us is one—the eighth, judging by the titles listed,—in a series called The Pageant of Progress. It is not a textbook although it might well be used as such in an informal study group. There are 158 pages of text divided into fourteen chapters. With a reasonable amount of attention and intelligence, the book can be read in a few hours, and thus a general survey of the vast field obtained.

The author writes clearly and convincingly, so that the reader is impressed with the thought that he is dealing with facts and not with speculations. And yet many pages are as fascinating as the most exciting fiction.

The usual classification of the heavenly bodies is observed in the several chapters. The concluding chapter entitled The Depth of Space is stimulating and challenging to thought and imagination. There are numerous diagrams and photographs very well reproduced. In a word, the book well deserves a place among the many books of its kind and will be found to be such as many amateur astronomers are desirous of having for reference.

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**Leben und Wirken des Johannes Müller von Königsberg genannt Regiomontanus,** by Ernst Zinner. (E. H. Beck'sche Verlagsbuchhandlung, Munich, Germany.)

The volume before us, which portrays the life and work of Johannes Müller of Koenigsberg, called Regiomontanus, is the thirty-first in a series of historical works relating to Bavaria. This particular one was prompted by the five hundredth anniversary of the birth of the subject of the volume. It is done in the usual finished and detailed manner characteristic of German works.

Among the many activities of this apparently unusually versatile person astronomy held an important place. It is said that he was engaged in a translation of the works of Ptolemy at the time of his death at the early age of forty. The extensive bibliographies and indexes constitute this a very useful reference work. There are 46 pages of plates of photographs, facsimiles, and tables at the end of the volume. It will be found of interest both to those historians and astronomers for whom the German language is no barrier.

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